Tectonic Implication of Pinwe-Mawlu Area, Indaw Township, Sagaing Region

Aung Khin Soe[1] and Wunna[2]

Abstract

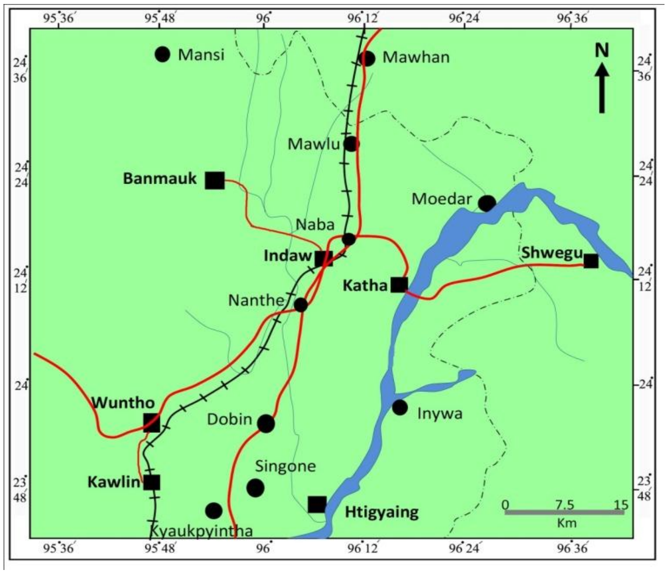
Myanmar is divided into Western Province and Eastern Province separated by Sagaing Fault. Western Province is Myanmar microplate and Eastern Province is a part of Shan-Thai Block. West Myanmar Province separated from Gondwana during Late Triassic to Late Jurassic, accreting to the Sibumasu Block in the Early Cretaceous and Indian Plate started drifting northward. West Myanmar Province collided with the Sibumasu Block in Late Mesozoic. Subduction and collision between Indian Plate and West Myanmar Province began Mid-Eocene and reached its peak in Oligocene. Due to the collision of Indian, Eurasian and Myanmar microplatelet created the Katha-Gangaw Range in the northern Myanmar Plate. The eastern part of west Myanmar Province was the strongest transformation effect in Pliocene due to continuous subduction of Indian Plate. The metamorphic of Katha-Gangaw Range is equivalent of the ophiolite of Indo-Burman Ranges and it is the northern offset continuation of the western Indo-Burman Ranges. Kyanite (sillimanite)-garnet schist of pelitic rocks and garnet-tschermakite schist of basic rocks of the present area have undergone high P-T conditions (~1.8 GPa/735°C). The sequence of metamorphic facies encountered in the study area could be compared to the high P facies series of Franciscan Type. As a result of the dextral movement of the Sagaing Fault, the metamorphic rocks of the Kumon Range and Katha-Gangaw Range reached to present position.

Key words: Gondwana, Sibumasu Block, Katha-Gangaw Range, ophiolite, Sagaing Fault

Introduction

The investigated area, Pinwe-Mawlu area, is situated in Indaw Township, northeastern part of the Sagaing Region. It lies between Latitude 24° 20′ to 24° 35′ N and Longitude 96° 10′ to 96° 20′ E. The area is bounded by vertical grids 140 to 280 and horizontal grids 940 to 150 in UTM maps of sheet No. 2496 02, sheet No. 2496 03, sheet No. 2496 06 and sheet N0.2496 07.The present area is about 21 km long in the N-S direction and 14 km wide in an E-W direction. It covers about 294 square km. The location map of the study area is shown in (Figure 1).

1 Dr, Professor and Head, Department of Geology, Banmaw University
2 Assistant Lecturer, Department of Geology, Monywa University



Distribution of Rock Units

The present study area is chiefly made up of metamorphic rocks with minor sediments. The metamorphic rocks are of Late Jurassic-Early Cretaceous Katha Metamorphic rock units and Miocene to Plio-Pleistocene Irrawaddy Formation. The pelitic to psammitic protolith may be inferred by the presence of predominant schist and quartzite of the investigated area. The presumable metabasite due to difference physical characters of surrounding rock units is occurred in the garnet biotite schist unit.

The Katha Metamorphics occupy both limbs of Katha-Gangaw Range and may be lithologically divided into eleven units (eight in metapelite, one in metabasite and two in metapsammite). They are (i) chlorite schist (ii) biotite schist (iii) muscovite schist (iv) garnet biotite schist (v) garnet muscovite schist (vi) paragonite garnet schist (vii) sillimanite garnet staurolite schist (viii) garnet kyanite (sillimanite) muscovite schist (metapelite) (ix) garnet actinolite schist (metabasite) (x) quartzite and (xi) micaceous quartzite (metapsammite). Garnet biotite schist is the most abundant metamorphic rock unit and this unit occupies the central and eastern part of the area.

Tectonic Implication

Myanmar can be divided into the Western province and the Eastern province, separated by the Sagaing Fault (Figure 2) (in Yui et al., (2013). The Western province is also named as the Myanmar microplate, whereas the Eastern province is part of the Shan-Thai block. The east dipping Andaman subduction zone that continues onshore along the western margin of the Western province (the Myanmar microplate) marks the presently active boundary with Indian plate to the west. (see Metcalfe, 2000; Mitchell, 1977; Mitchell *et al*., 2007 and Searle *et al*., 2007).

The collision process of Indian Plate, Eurasian Plate and Myanmar Platelet created the Himalayan Thrust-Fold Belt (HTFB) and Arakan-Yoma Fold Belt (AYFB) in Indian Plate

Margin; Jade Mine Belt (JMB), Katha-Gangaw Ranges (KGR), Tagaung-Myiktina belt (TMB) and Mogok Metamorphic Belt (MMB) in Northern Myanmar (Figure 3) (see Ningthoujam *et al.*, 2015).

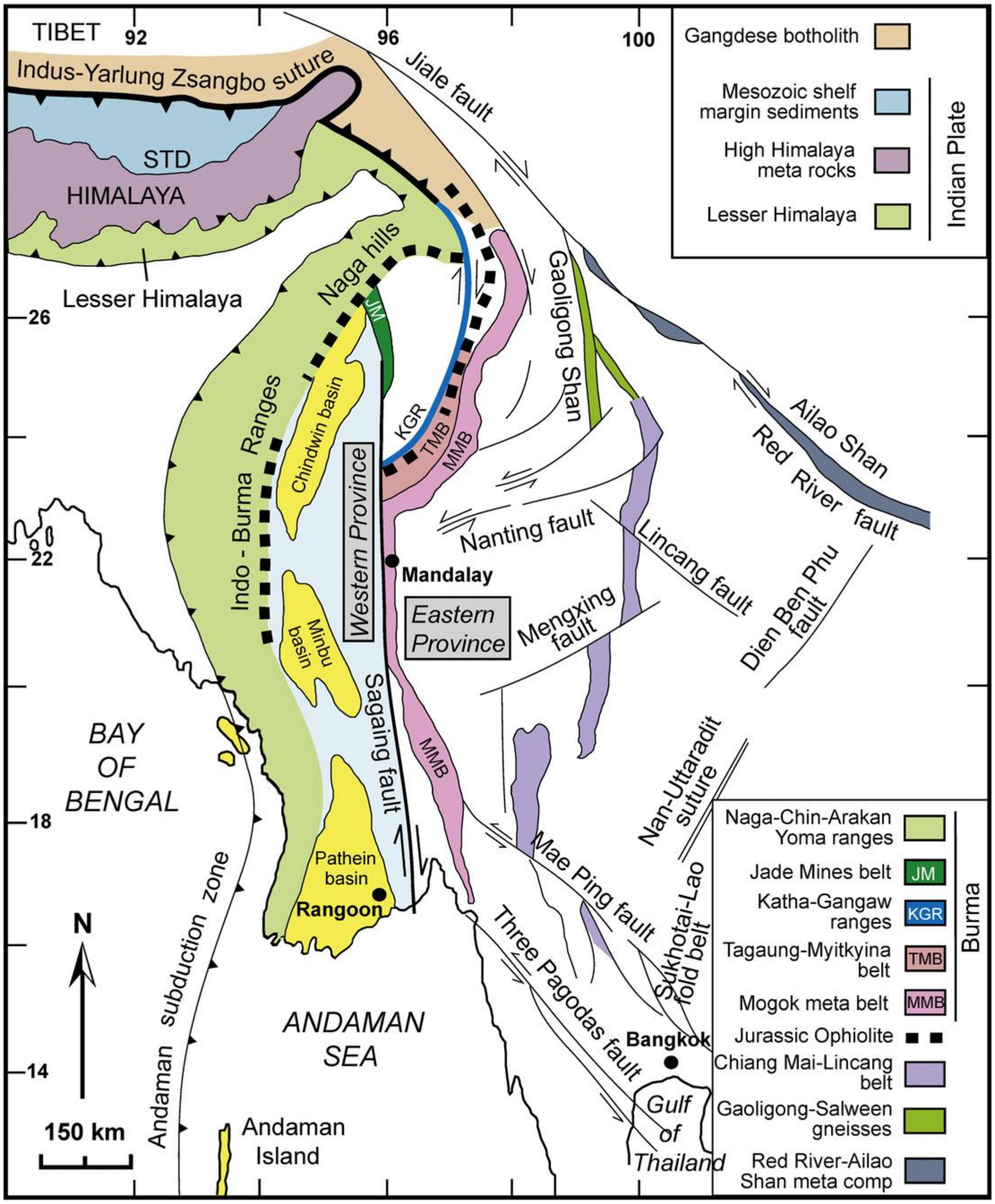


Figure (2) Geologic overview of the Myanmar area modified after Searle *et al.,* 2007. (Source: Yui et al., 2013)

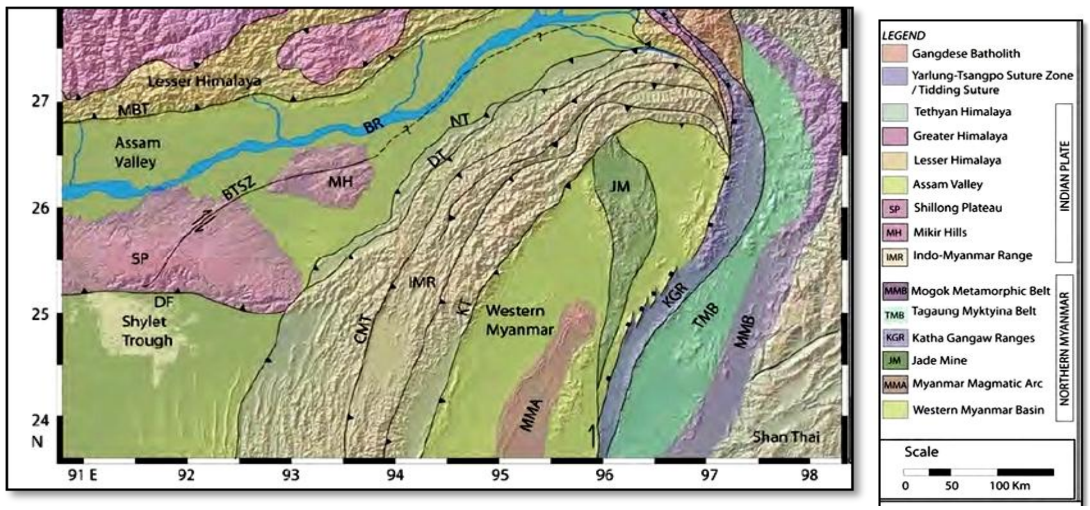


Figure (3) Geological map of northern Myanmar Platelet and surrounding region (Modified after Searle *et al*., 2007; Yin *et al*., 2010a; Ningthoujam *et al.*, 2012).; MCT – Main Central Thrust; MBT – Main Boundary Thrust; SP – Shillong Plateau; BTSZ – Badapani Trysad Shear Zone; MH – Mikir Hills; DF – Dauki Fault; BR – Brahmaputra River; PF – Pugu Fault; JF – Jaile Fault; NT – Naga Thrust; DT – Dishang Thrust; CMT – Churchandpur Mao Thrust; IMR – Indo Myanmar Range; KT– Kabaw Thrust; JM – Jade Mines Belt; KGR – Katha-Gangaw Ranges; TMB – Tagaung- Myiktina belt; MMB – Mogok Metamorphic Belt (Source: Ningthoujam et al., 2015).

The KGR contains high-grade gneissic rocks which lie on eastern side of TMB schist and are assumed to be northern continuation of the MMB (Mitchell et al., 2007). These metamorphic belts were subjected to low/medium pressure-high temperature condition whereas, the JMB were formed under high pressure metamorphism (Searle et al., 2007). In the JMB, serpentinised peridotite boulders are found in alluvial deposits with pure jadeite, amphibole jade and kyanite-bearing omphacite jade. The MMB is composed of high grade metamorphic rocks and contains sapphire-bearing nepheline syenites with host rock phlogopite-diopside marbles and these host rocks contain gem-quality rubies and spine (Iyer, 1953; Kane and Kammerling, 1992 in Ningthoujam et al., 2015).

The western Myanmar microplate of the Indo-Burman Ranges is composed mainly of Upper Cretaceous–Paleogene marine sedimentary rocks unconformably overlying Upper Triassic flysch-type sediments and associated Jurassic ophiolitic rocks. To the east of the Indo-Myanmar Ranges, there are a series of mid-Cretaceous to Miocene sedimentary basins (Chindwin, Minbu and Pathein basins). Along with the basins, a belt of calc-alkaline Late Cretaceous plutons and Cenozoic volcanoes signifies the long-lived Andaman subduction system (in Yui et al., 2013).

The Eastern province of Myanmar is composed of the Paleozoic Mogok metamorphic belt (MMB) to the west and the Upper Carboniferous–Lower Permian Mergui Group metasediments to the east (Mitchell, 1992, 1993). Subduction-related Jurassic–Miocene granites intruded to the Mogok metamorphics.

Curray et al., (1979) suggested that the West Myanmar Province is located in the area of the active continental margin fore-arc basin, island arc and back-arc basin, which is in the convergent area of Indian Plate and Eurasian Plate. It is bounded by Sagaing Fault to the east, adjacent to Bengal Basin to the west, neighbouring the China Plate and the Himalayan fold belt to the north, and bordered by Andaman Sea spreading center to the south.

West Myanmar Block (Western Province), located at the convergence zone of Southeast Asia, is characterized by frequent tectonic activities, abundant and complicated geological features (Metcalfe, 2006). As a typical active continental margin, West Myanmar Block separated from Gondwana, and converged with other microplates by a series of drifting from Paleozoic to Mesozoic (Acharyya, 2000; Metcalfe and Irving, 1990; Audley-Charles, 1988; Metcalfe, 1988; Sengör, 1984), resulting in its characteristics of tectonic evolution from passive continental margin to active continental margin (in Li et al.,2013).

Metcalfe (2006) established the splitting sequence and the evolution model of the original Southeast Asia blocks. With the rifting of West Myanmar Block and its separating from Gondwana during Late Triassic to Late Jurassic and accreting to the Sibumasu Block (nowadays, Myanmar was divided into West Myanmar Block and Sibumasu Block by Sagaing Fault as shown in (Figure 4) in the Early Cretaceous, India Plate started drifting northward and Ceno-Tethys subducting beneath Southeast Asia.

The N–S trending Sagaing Fault is a 1200 km long dextral fault and the distance of the displacement has been estimated from less than 100–150 km (Bertrand and Rangin, 2003) to ~450 km (Mitchell, 1993) or even more. The fault connects to the Andaman back-arc spreading centre in the south whilst it splays into three prominent metamorphic belts within the Western province in the north. These three metamorphic belts, from west to east, are the Jade Mines belt (JM), the Katha-Gangaw ranges (KGR) and the Tagaung-Myitkyina belt (TMB). Mitchell (1993) stated that the Jade Mines belt has been subjected to high-pressure metamorphism, whereas low- to medium-pressure/high-temperature metamorphic rocks prevail in the Katha-Gangaw ranges and the Tagaung-Myitkyina belt (in Yui et al., 2013).

Initial "soft" collision between the India Plate and Eurasian Plate occurred during the Paleocene (Wandrey, 2006), and "hard" collision occurred during the Middle Eocene (Metcalfe, 2006). With the development of ophiolite belt and accretionary prism in West Myanmar Block, as well as the magmatic intrusion and volcanic arc uplifting, the tectonic system of typical active continental margin, trench—accretionary prism— fore-arc basin—volcanic arc—back-arc basin, was formed along Indo-Myanmar orogenic belt and Andaman Islands (Acharyya, 2007; Curray, 2005; Nielsen et al., 2004; Pal et al., 2003 and Curray et al., 1979 in Li et al., 2013).

With the re-interpretation of tectonic evolution of Sundaland, Metcalfe (2011) proposed that West Myanmar Block rifted and separated from Gondwana in Devonian, then accreted to the Sibumasu Block from Late Permian to Early Triassic, and slipped westward along the boundary fault. By discovering the flysch unit of Late Eocene to Miocene in Indo-Myanmar ranges, Bannert and Helmcke (1981) established the evolution model of West Myanmar Block since Cenozoic. It was also inferred that West Myanmar Block transformed from passive continental margin to active continental margin in Eocene. Furthermore, the West Myanmar Block is regarded as an Early Cretaceous mafic arc. It was produced by southwest directed subduction, then was thrusted onto the Asian margin from Late Jurassic to late Early

Cretaceous (Mitchell, 1993), and finally evolved into an active continental margin with trench-arc-basin system in Middle Miocene.

On the eastern side of the West Myanmar Block, against the Sagaing Fault, the basement of the West Myanmar Block is represented by the Mayathein Metamorphic Group composed of gneisses, schists and migmatites, with minor calc-silicates, marbles and amphibolites (Myint Thein, 2015).

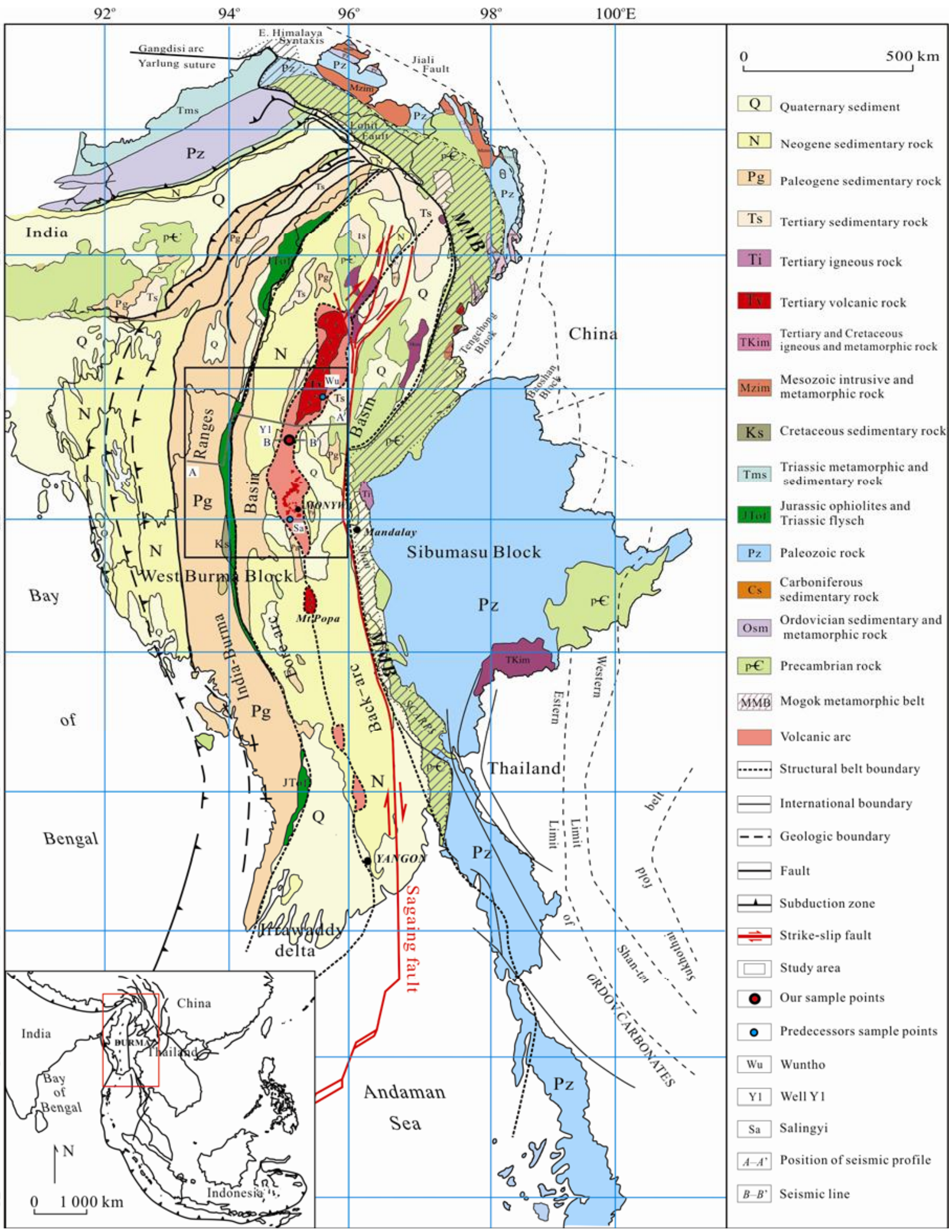


Figure (4) Regional geologic map of Myanmar modified after Mitchell *et al*., 2012; Wandrey, 2006 (Source: Li et al., 2013)

Thet Tin Nyunt et al. (2017) reported that the Jade Belt, northwestern part of the study area lies between the Chindwin and Upper Ayeyawaddy rivers. Jadeitite occurs as pods and lenses within serpentinized peridotite bodies, and is worked in quarries and mines or is retrieved as boulders from the alluvium of the Uru River. The serpentinite bodies are surrounded by metamorphic rocks formed at high pressure but at low–medium temperatures, including eclogite, garnet–mica schists, glaucophane schists, amphibolite schists, epidote schists and marble. The higher-grade metamorphic rocks show varying degrees of alteration towards the greenschist facies. Jadeitite pods are commonly surrounded by reaction zones of albitite, actinolite and chlorite schist. The P-T conditions of this belt is 1-1.5 GPa at comparatively moderate T of 300-400°C (in Barber et al., 2017)

Discussion

The tectonic significance and metamorphic evolution of the present area is likely to be subjected to similar tectonic regime of the surrounding regions. However, various approaches of different authors create the possible tectonic models of Myanmar including the present area (e.g. Win Swe, 1972; Maung Thein, 1983; Hutchison, 1989, 2007; GIAC, 1999; Mitchell et al., 2007). The tectonic and metamorphic evolutions of the surrounding areas are reconstructed by Aung Kyaw Thin (2006), Aung Win (2008), Nyan Win (2008), Khin Pyone (2009) and Thaire Phyu Win (2011).

In the tectonics of Myanmar region, the Indian and Southeast Asia Plates are separated by the wedge-shaped Myanmar Plate, which is bounded by the Sagaing Fault in the east and either the Kabaw fault zone or the foreland thrust to the west. Within this Myanmar Plate, Indo-Myanmar Ranges is located above the shallower dipping part of the subduction zone (Win Swe, 1981).

Khin Zaw (1990) suggested a possible restoration of the granitoid belts in Myanmar as a pre-displacement position and he assumed an optimum value of 250 km northward dextral movement along the Sagaing Fault (Late Miocene). According to his opinion, Wuntho granitoid body lies immediately at the west of the Pyetkaywe pluton. Thus, Sagaing Fault was responsible for the northerly displacement of the Myanmar Plate together with the western ophiolite belt (Hla Htay, 2000) of Myanmar.

The West Myanmar Block (Myanmar Plate) collided with the Sibumasu Block in the Late Mesozoic. With the subduction of Neo-Tethys Ocean, it started to convert from passive continental margin to active continental margin (Metcalfe, 2006), corresponding to the development of different tectonic systems in active continental margin and tectonic response, adjustment and reconstruction of different basins in structural belt.

Xie et al. (2010) mentioned the subduction and collision between Indian Plate and West Myanmar Block began in Middle Eocene and reached its peak in Oligocene. Bertrand et al., (2001) obtained $^{40}Ar/^{39}Ar$ of 26–21 Ma on samples near Mandalay and interpreted as upliftcooling ages in the Mogok metamorphic belt (MMB) of West Myanmar Block. Searle et al., (2007) and Mitchell et al., (2012) reported that the uplift-cooling age following the metamorphic event was probably in the 43–29 Ma interval. Based on zircon U-Pb dating, Mitchell et al. (2012) obtained zircon U-Pb ages of 17, 20 and 21 Ma, which were widely distributed within the MMB and were in agreement with the uplift-cooling age in the MMB describing by Bertrand et al. (2001). That the Indochina Plate presumably escaped with the collision between the Indian Plate and West Myanmar Block, the intense dextral strike-slip along the Sagaing Fault zone between West Myanmar Block and Sibumasu Block resulted in the existence of contact metamorphism crystallization age in the MMB from Middle Eocene to Late Oligocene (43–29 Ma). The MMB was uplifted between 26 and 21 Ma due to sustained subduction and collision, which revealed that the regional uplift-cooling time and contact metamorphism crystallization age (21–17 Ma) with the influence of strike-slip of Sagaing Fault (see Li et al., 2013).

Li et al.(2013) proposed that the right-lateral strike-slipping of Sagaing Fault zone in the east of West Myanmar Block was with the strongest transformation effect on the northern onshore area in the Pliocene due to the continued subduction of the Indian Plate. The Sagaing Fault zone uplifted significantly in this time.

The Sagaing Fault, a major N–S dextral strike slip fault in Myanmar separates the Myanmar microplate to the west from the Shan plateau of Asia (Sundaland) to the east. Vigny et al. (2003) suggested that the northern end of the Sagaing Fault splays into several branches, one of which may be continuous with the Mishmi thrust. High-grade kyanite and garnet-bearing schists occur in the Katha-Gangaw and Kumon belts parallel to and on the concave side of the suture near the intersection of the Sagaing Fault. Enami et al., (2012) reported an eclogite boulder probably originating from the Kumon range yielded P–T conditions of 1.2–1.3 GPa and 530–615°C. Similar P–T conditions of >1.4 GPa and 550–600°C were also determined from the high pressure rocks of the Jade Mines belt at the northwestern branch of the Sagiang Fault (Goffé et al., 2000). U–Pb zircon dates of 146.5 ± 3.4 Ma and 158 ± 2 Ma in jadeitites from the Jade Mines belt indicate subduction in Late Jurassic perhaps beneath the Sundaland margin (Searle and Morley, 2011).

Yui et al. (2013) stated that the Myanmar jadeitites should have formed during the Late Jurassic (i.e., 158–147 Ma) subduction between the Indian plate and the Myanmar microplate. Shi et al. (2008) related this subduction with some Mesozoic subduction-related calc-alkaline magmatism at 170–120 Ma along the Mogok belt. Mitchell et al. (2012) preferred to relate the intrusives along the Mogok belt to the subduction–collision with the Shan-Thai block, rather than to the subduction of the Indian plate. Qiu et al. (2009) also denied the connection between the inferred Jurassic subduction and the Mogok belt, but suggested a genetic relation with the Katha-Gangaw ranges (Figure 2). It is noted that eclogite was recently reported west of the Katha-Gangaw ranges (Enami et al. 2012) (in Yui et al., 2013).

Acharyya (2007) mentioned that the east of the Indo-Burman Ranges, there are two belts of dismembered ophiolites signifying the ancient plate boundary. The Myanmar jadeitite and HP rocks in the Jade Mines belt are considered to be part of these belts. The on-land emplacements of these ophiolitic rocks were suggested to have taken place during Early Cretaceous to mid-Eocene.

On the bases of $^{39}Ar/^{40}Ar$ phengite dating for HP rocks, Goffé et al. (2002) postulated that eclogite facies metamorphism of the Jade Mines belt took place at around 80 Ma. The (minimum) age of jadeitite formation, 77±3 Ma is in accord with this time frame and implies a Late Cretaceous subduction event. This age is older than the age of Himalayan ultrahigh-pressure gneisses, 53–46 Ma. It can therefore be concluded that the high-pressure rocks from the Jade Mines belt in northern Myanmar should be products during Late-Cretaceous subduction before India-Asia continental collision.

Kyanite-garnet schist in pelitic rocks of the Mohnyin area, northern continuation of the investigated area, has undergone high P/T (~1.9 GPa/750°C) metamorphism, which is slightly lower than those of basic schists from the eclogite unit (2.3 GPa/493°C) in the Mogaung area. Garnet-barrosite schist in the basic rocks of Katha area, southern continuation of the study area, has experienced high P/T condition (~1.5 GPa/580°C). Kyanite (sillimanite)-garnet of pelitic rocks and garnet-tschermakite schist of basic rocks of the present study area has undergone high P/T conditions (~1.8 GPa/735°C). This P-T points out that the metamorphism in the present area is a subduction related metamorphic complex.

Moreover, garnet-mica schist from metapelite of Tigyaing area (southern continuation of the study area) contains paragonite mica. These facts indicate that not only the metapelites and metabasites of the Katha-Gangaw Range but also the Kumon Range have undergone high P/T conditions. However, the peak conditions of Kanpetlet schist (metapelite) in Indo-Burman Ranges are around 0.8-0.9 GPa and 450°C (Socquet et al. 2002). They showed that the metamorphic rocks of the Indo-Myanmar Ranges underwent the early Tertiary thermobarometric evolution within a thick wedge underthrust beneath the ophiolite. They supposed that the obducted ophiolite might have served as a backstop under which the accretionary wedge in process of internal thickening. This model is close to the one proposed for high pressure-low temperature metamorphism in Oman (Goffé et al., 2002).

Chatterjee et al. (2010) indicated that the Naga Hills barrosite eclogite (metabasite) is beginning at 1.3 GPa/525°C and peaking at 1.7-2 GPa/580-610°C, and subsequent retrogression to 1.1 GPa/540°C. The metamorphic of the Katha-Gangaw Range may be the equivalent of the ophiolite of the Indo-Burman Ranges (Mitchell, 1993), whereas the western Jade Mines contain eclogite facies rocks metamorphosed at >1.4 GPa/550-600°C (Goffé et al., 2002).

In the Assam region and Indo-Burman Ranges there are medium-to high pressure metamorphic rocks and similarly, medium-high pressure and low-high temperature metamorphic rocks in the Kumon Range, Katha-Gangaw Range and Tagaung-Myitkyina belt. Therefore, according to the above mentioned documents and the suggestions of Mitchell (1993), the metamorphic rocks of the Katha-Gangaw Range and Kumon Range are the northern offset continuation of the metamorphic rocks of the western Indo-Burman Ranges.

Mitchell et al. (2007) proposed that the age of metamorphism is two possibilities; either (1) there are three stages of metamorphism during Early Permian, Early Jurassic and Early Tertiary time, respectively, or (2) there are two stages of metamorphism during late Cretaceous and Early Tertiary time, respectively. Beside, Searle et al. (2007) suggested that metamorphism occurred during Jurassic–Early Cretaceous, Paleocene– Early Eocene and Late Eocene-Oligocene time (in Yui et al., 2013).

Barber et al. (2017) reported that India separated from Australia and Antarctica in Gondwana at about 120 Ma (Early Cretaceous), and moved northwards, driven by the expansion of the Indian Ocean in the south and the subduction of Neotethys beneath Eurasia in the north. It is considered that the Indian Continental Plate, which included its northern extension Greater India, began to collide with the southern margin of Eurasia in the region of Tibet at 50 Ma (Early Eocene). As the continental plate drove beneath Asia, the intervening oceanic crust was crushed to form the Yarlang–Tsangpo Suture in Tibet marked by ophiolites and ocean floor sediments, and the northern continental margin sediments of India were thrust backwards onto the advancing Indian continent to form the Himalayas. At the commencement of the collision, it is considered that the tectonic units which presently make up Southeast Asia were orientated approximately NW–SE (Figure 5).

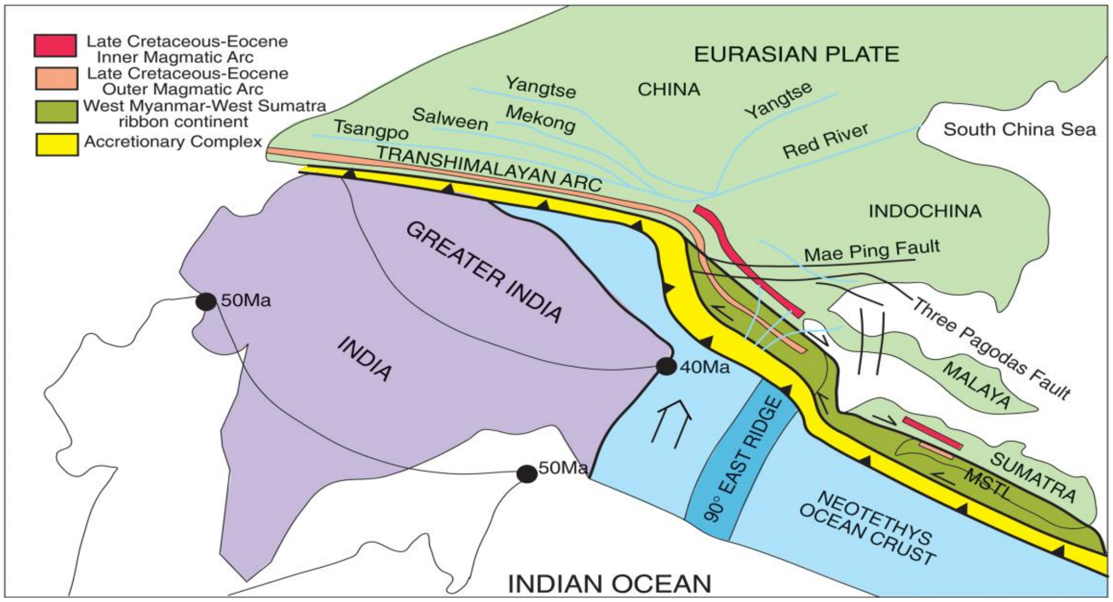


Figure (5). Diagrammatic representation of the progress of the collision between India and the southern margin of Eurasia at 50 and 40 Ma, after Morley (2004). (MSTL is the Medial Sumatra Tectonic Line) (Source: Barber et al., 2017)

As the collision progressed and India pushed forwards into Asia, compression and thickening of the crust in the Tibetan region caused crustal material to be extruded eastwards and, rotating the crustal components of Southeast Asia through 70° to reach their present north–south orientation. Differential movement between crustal blocks was accommodated by major strike-slip faults such as the Paunglaung Fault in Myanmar and the Ailaoshan-Red River Fault System in southern China and Vietnam, accompanied by complex flow patterns in the Lower Crust. The northwards movement and oblique subduction of the Indian Plate beneath Sumatra and Myanmar, and the southeastwards movement of Southeast Asia, set up shearing stresses within the eastern margin of the Asian crust. The effects of these stresses within Myanmar were oblique extension indicated by the lineations in the gneisses of the Mogok Belt, and the opening of the en echelon Central Myanmar sedimentary basins. Continued northwards movement of the Indian Plate in the Miocene led to dextral strike-slip movement along the Sumatran and Sagaing faults in Sumatra and Myanmar and the opening of the Andaman Sea.

Concluding Remark

Based on the results of zircon U-Pb dating and apatite fission track analysis, Li et al.(2013) concluded that the West Myanmar Block evolved from passive continental margin to active continental margin because of the subduction of Neo-Tethys Ocean during late Early Cretaceous (102±0.81 Ma). The West Myanmar Block had evolved into active continental margin by the subduction and collision of Indian Plate from Late Oligocene to Early Miocene (29±1 to 20±1 Ma). The active continental margin trench-arc-basin system of the West Myanmar Block was basically fixed since Early Pliocene (4.2±1 Ma).

Shi et al.(2014) reported that the Jurassic HP/LT rocks have not been found in the MMB. Furthermore, an Andean type margin of southern Eurassia, instead of an intra-oceanic subduction for the jadeite is suggested from Jurassic magmatic zircons in the Mogok belt. Searle et al., (2007) mentioned that the nearly 43 Ma age for high grade metamorphism revealed by overgrowth on Jurassic zircons in the orthogneiss near Mandalay is almost the same as the age of $^{40}Ar/^{39}Ar$ dating suggesting similar events related to the Indian-Eurassian collision.

Shi et al., (2014) also suggested that the nearly 45 Ma (Eocene) for phengitic muscovite in JM is interpreted as continental deformation age, being coeval with the event induced by the India-Eurassia collision, and close to the timing of formation of the Sagaing Fault.

The relationship between the Katha-Gangaw Range and the western Indo-Burman Ranges is very close and clear. Mitchell (1993) proposed an offset of nearly 450 km based on the displacement of pre-Albian ophiolitic rocks from the Mt.Victoria belt in the west to the Tagaung-Myitkyina belt in the northern Myanmar.

Indo-Burman Ranges, including mica schists are possibly the southward continuation of the Katha-Gangaw Range, offset right laterally over 300 km on the Sagaing Fault. In the northern Myanmar, most of the metamorphic rocks are low-medium pressure and low-temperature rocks whereas the Jade Mines belt has been subjected to high pressure metamorphism.

The present study argued that in the above mentioned areas there was no found high grade gneiss and all of these metamorphic rocks are high-temperature rocks (e.g. SW of Kumon Range –low temperature and W of the Katha-Gangaw Range (Mohnyin area) –high temperature, Tagaung-Myitkyina belt –high temperature, west of Katha-Gangaw Range (Pinwe-Mawlu and Katha area)-medium to high temperature conditions) whereas the Jade mines belt has been subjected to high-pressure metamorphism.

Figure (6) is the schematically possible restoration of the plate tectonic evolution of northern Myanmar including the study area during Late Mesozoic to Recent interval. Based on the broad sense of the global regional tectonic evolution of Southeast Asia, under the seismotectonic data and GPS measurements of the previous authors, available field and laboratory data on the petrogenesis of the present area, the reconstructive model is prepared.

(1)During the Late Mesozoic (Late Jurassic to late Early Cretaceous), northward or northeastward subduction of Indian Plate beneath the Eurasian Plate (Tibet and Shan-Thai Block of Southeast Asia) occurred together with the igneous activity. The deposition of pelagic sediments and Mesozoic carbonates are formed on the continental shelf during Tethys subduction. During this time, high pressure metamorphic rocks of garnet-tschermakite schist begun to be recrystallized and high temperature, simultaneously, sillimanite grade metamorphic belt in the western margin of the Shan Plateau as Mogok Metamorphic Belt (Figure 6 A).

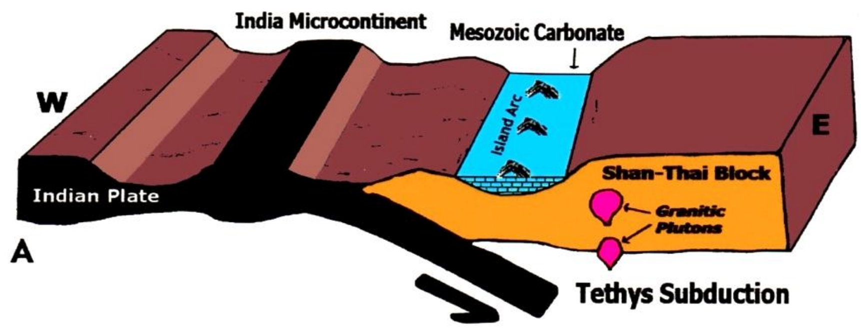


Figure (6 A) Possible schematic tectonic model of the northern Myanmar including the study area during Late Jurassic to Early Cretaceous (Modified after GIAC, 1999 and Thaire Phyu Win, 2011)

(2) During Late Cretaceous to Early Tertiary, the collision between India and Asia, and the continuous subduction zone began to change shape. After this, crustal shortening happened and trench was filled and mixed by pelagic and mollasic sediments, igneous materials into the trench fill sediments. The Tethyan ophiolites were obducted onto a leading edge of the Indo-Myanmar Ranges. The eastward thrusting of Shan-Thai Block has been formed due to crustal thickening and folding. During the Early Tertiary to Early Oligocene, some earlier older ones are obducted onto the continental margin of the Shan-Thai Block for a certain distance. Then, the Central Myanmar Basin was constructed and westward thrusting of Shan-Thai Block was formed after the crustal relaxation. This tectonic process not only exhumed the high-pressure metamorphic rocks but also extended the surrounding regions and linked to the intrusion of igneous rocks. Resultant of this event created the increment of pressure and temperature conditions for garnet-tschermakite schist (Figure 6 B).

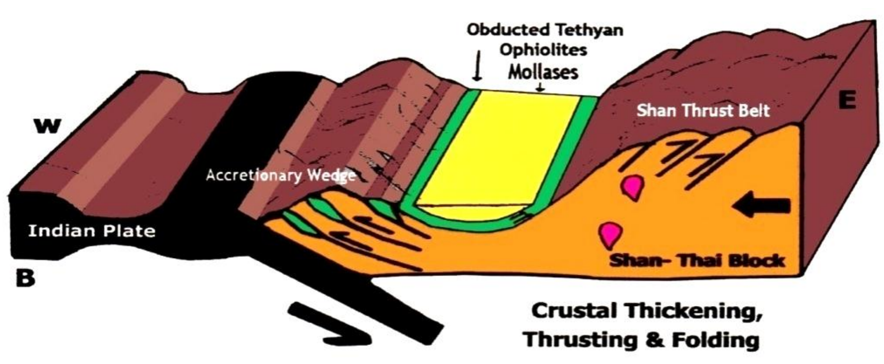


Figure (6 B) Possible schematic tectonic model of the northern Myanmar including the study area during Late Cretaceous to Early Eocene (Modified after GIAC, 1999 and Thaire Phyu Win, 2011)

(3) In the duration of Late Oligocene to Middle Miocene, the eastern part of accretionary wedge of the Indo-Burman Ranges thrust over the molasses easterly and Shan scarp fault appears during the crustal extension and thinning. During this time, the collision between India and Eurasia resulted in the numerous transpressional structures (Figure 6 C).

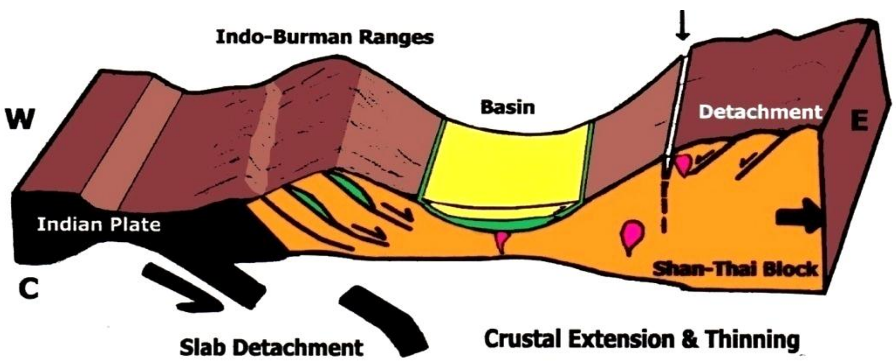


Figure (6 C) Possible schematic tectonic model of the northern Myanmar including the study area during Late Oligocene to Middle Miocene (Modified after GIAC, 1999 and Thaire Phyu Win, 2011)

(4) During Late Miocene to Recent, the right lateral Sagaing Fault has developed related to the spreading of Andaman Sea. Contemporaneously, the Kabaw Fault is formed normally along the western margin of Myanmar Plate. Due to the westward migration of east-dipping oblique convergence of the Indian Plate, the igneous activity of Central Volcanic Arc is formed. As a result of the dextral movement of the Sagaing Fault, the metamorphic rocks of the Kumon Range and Katha-Gangaw Range reached to present position (Figure 6 D).

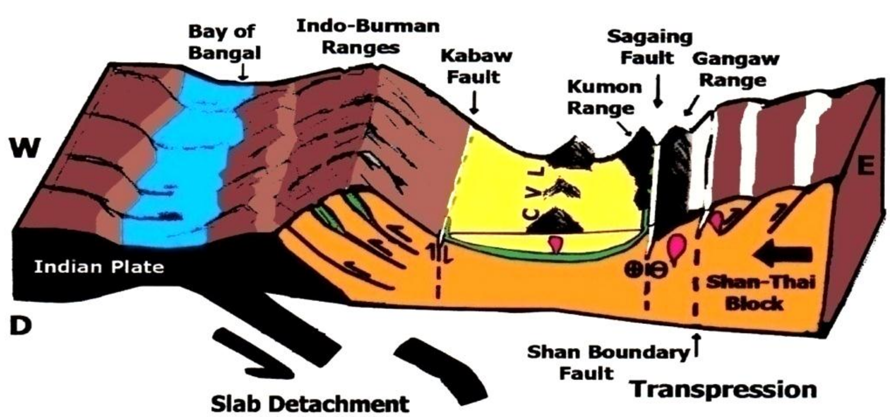


Figure (6 D) Possible schematic tectonic model of the northern Myanmar including the study area during Late Miocene to Recent (Modified after GIAC, 1999 and Thaire Phyu Win, 2011)

Acknowledgements

We would like to express our thanks to Dr Aung Kyaw Thin, Acting Rector and Dr Aye Aye Han, Prorector of the Banmaw University for their encouragement to conduct this research. Special thanks go to all local people of the Pinwe and Mawlu villages for their valuable help throughout the field trip. Finally, all our colleges from Geology Department, Banmaw University are highly thanked for their cooperation.

References

Aung Kyaw Thin, (2006). Petrogenetic study on igneous and metamorphic rocks of the Tagaung-Twinnge area, Thabeikyin Township.Ph.D (Dissertation), Geology Department, Mandalay University, Unpublished Paper, 123 p.

Aung Win, (2008). Petrogenetic studies of metamorphic rocks in Mogaung area, Mogaung and Phakant Township, Myitkyina District, Kachin State.Ph.D (Dissertation), Geology Department, Mandalay University, Unpublished Paper. 183p.

Barber, A.J.,Khin Zaw and Crow, M.J., (2017). *Myanmar:Geology, Resources and Tectonics*. Geological Society, London, Memoirs, 48, 689-717.

Bucher, K. and Frey, M., (1994).*Petrogenesis of Metamorphic rocks*. 6thed, Springer-Verlag Berlin Heidelberg, printed in Germany.

Bucher, K. and Grapes, R., (2011). *Petrogenesisof Metamorphic rocks*.8thed, Springer-Verlag Berlin Heidelberg, printed in Germany.

Chatterjee, N., and Ghose, N.C., (2010). Metamorphic evolution of the Naga Hills eclogite and blueschist, Northeast India: implication for the early subduction of the Indian plate under the Burma microplate. *Journal of Metamorphic Geology*. V. 28, pp. 209-225

Ghose *et al.,* (2014). Ophiolite Around the Indian Plate Margin. *A Petrographic Atlas of Ophiolite*. DOI: 10.1007/978-81-322-1569-1-2 © Springer India, 2014

G.I.A.C, (1999). The Tectonic of Myanmar. *Final Report of G.I.A.C Project*. 1996-1999. 156p.

Goffe, B., Rangin, C.,and Maluski, H., (2002).Jade and Associated Rocks from the Jade Mine Area, Northern Myanmar as Record of a Polyphased High-Pressure Metamorphism, Himalaya-Karakoram-Tibet Workshop Meeting (Abstract). *J. Asian Earth Sci.*,20,16-17.

Hla Htay, (2006).Geology of the Inkhaing Bum- Myitson area, Myitkyina Township. Unpublished. PhD Dissertation, Dept. Geol. Yangon University.

Hutchison, C.S., (2007). *Geological Evolution of South-East Asia*. 2nd .Geological society of Malaysia. Art Printing Works Sdm. Bhd. Malaysia. 406p

Hyndman, D.W., (1985). *Petrology of Igneous and Metamorphic rocks*.2nded.Mc.Graw Hill, Inc, New York.

Khin Pyone, (2009). Petrogenesis of the metamorphic rocks of the Gangaw Range, Katha and Tigyaing Townships, Sagaing Division. Unpublished. PhD Dissertation, Dept. Geol. Mandalay University. 99p.

Li *et al.,* (2013). Late Mesozoic to Cenozoic Tectonic Events in Volcanic Arc, West Burma Block: Evidences from U-Pb Zircon Dating and Apatite Fission Track Data of Granitoids. *Journal of Earth Science*, Vol. 24, No.4, p. 553-568, August (2013)

Mitchell *et al.,* (2006). Rock relationships in the Mogok metamorphic belt, Tatkon to Mandalay, central Myanmar. *Journal of Asian Earth Sciences (2006),* doi:10.1016/j.jseaes.2006.05.009

Mitchell, A.H.G., (1993). Cretaceous-Cenozoic tectonic events in the western Myanmar-Assam Region. *Journal of the Geological society of London*. V. 150, pp.1090-1102

Myint Thein, (2015). The Pre-Tertiary carbonate rocks exposed at the NE margin of the Central Myanmar Basin and their development history. *Journal of the Myanmar Geosciences Society*, 6.1-16

Ningthoujam *et al.*, (2015). Tectonic studies and crustal shortening across Easternmost Arunachal Himalaya. *Journal of Asian Earth Sciences* 111 (2015) 339-349

Nyan Win, (2008). Petrogenetic study of the metamorphic rocks in Mohnyin-Namma-Hopin area, Mohnyin District, Kachin State. Ph.D (Dissertation), Geology Department, Mandalay University, Unpublished Paper, 133p.

Raymond, L. A., (1995). *Petrology: The Study of Igneous, Sedimentary and Metamorphic rocks.* Wm.C Brown Publishers. 742p.

Shi *et al.*, (2014). Superimposed tectono-metamorphic episodes of Jurassic and Eocene age in the jadeite uplift, Myanmar, as revealed by 40Ar/39Ar dating. *Gondwana Research* 26 (2014) 464-474

Thaire Phyu Win, (2011). Petrology of the Katha metamorphic between Indaw and Katha, Sagaing Division.Ph.D (Dissertation), Geology Department, Mandalay University, Unpuplished Paper, 121p.

Tinkham.K and Ghent.D, (2005). Estimating P-T Conditions of Garnet Growth with Isochemical Phase-Diagram Sections and the Problem of Effective Bulk-Composition. *The Canadian Mineralogist*. Vol.43,pp. 35-50 (2005)

Winter, J.D., (2010).*An Introduction to Igneous and Metamorphic Petrology*.2nd ed. Prentice Hall, New Jersey.

Yardley, B.W. D., (1989).*An Introduction to Metamorphic Petrology*. Longman Group Ltd.

Yardley, B. W. D., McKenzie, W. S., and Guilford, C., (1990). *Atlas of Metamorphic Rocks and their Textures*.Longman Scientific and Technical, John Wiley and Sons, Inc. New York**.**

Yui *et al.*, (2013). Is Myanmar jadeitite of Jurassic age? A result from incompletely recrystallized inherited zircon. *Lithos* 160-161 (2013) 268-282

Occurrence of Permian Giant Bivalve (Alatoconchidae) from Pindaya Range, Shan State (south), Myanmar

Kyi Pyar Aung[1], Yukio Isozaki[2]

Abstract

Alatoconchidae, a unique bivalve family from the Permian, was found in the Guadalupian (Middle Permian) shallow marine limestone in the Pindaya Range of the southern Shan Plateau, for the first time in Myanmar. This bivalve family is characterized by a giant body size, by unusual shell form with wing-like flanges, and by coarse-grained prismatic outer layer of the shell wall. The newly found alatoconchids commonly form coquina beds, and co-occur with rugose corals (*Lophophyllidium*, *Ipcyphyllum* etc.) and bryozoans. Palaeogeographically, they are restricted to low-latitude Tethyan and Panthalassan regions. Alatoconchidae likely became extinct globally at the end of the Guadalupian.

Keywords: Alatoconchidae, Guadalupian, Myanmar, Tethyan, Gigantism, Extinction

Introduction

The Permian bivalve family Alatoconchidae is characterized by extraordinarily large size and aberrant morphology so different from other ordinary bivalves (Fig. 1); therefore, it was treated as a paleontological problematica when first describes from Japan in the late 1960s (Ozaki, 1968). The occurrences of this unique Permian bivalve family have been previously reported from twelve areas in the world, i.e., from eight Tethyan areas: Tunisia, Croatia, Oman, Iran, Afghanistan, South China, Malaysia, Thailand, and from three mid-Panthalassan domains (Japan, Philippines, and Alaska) (Isozaki, 2006; Aljinovic et al., 2008; Isozaki & Aljinovic, 2009; Blodgett and Isozaki, 2013). Alatoconchidae almost always co-occurred with large-tested fusulines (Verbeekinidae) and/or rugose coral (Waagenophyllidae) of the typical Tethyan assemblage, suggesting their prudential adaptation to shallow warm-water (tropical) environments (Isozaki & Aljinovic, 2009). In fossil records, gigantism of bivalves discontinuously occurred several times in the Phanerozoic, i.e., Siluro-Devonian megalodonts, Permian alatoconchids, Late Triassic-Early Jurassic megalodonts, and Late Jurassic-Cretaceous rudists/inoceramids, Miocene-recent tridacnids, in particular, during warm periods (Fig. 2).

Objective of Study

This article reports the first occurrence of Alatoconchidae from the Shan massif in Myanmar, and discusses its plaeogeographical significance.

1 Dr, Professor, Department of Geology, Banmaw University

2 Professor, Department of Earth Science and Astronomy, The University of Tokyo

Geologic Setting

The study area near Pindaya in eastern Myanmar is located in the quadrangle between 20° 54´ 50"N and 20° 52´ 25"N, and between 96° 37´ 50"E and 96° 41´ 55"E (one inch topographic map 93 D/9) (Fig. 3). The geology of the area, with special reference to mineralization, stratigraphy, and paleontology, has been previously analyzed by various researches, as represented by rich geological literatures on northern/southern Shan State since the British colonial days. In particular, basic mapping works by Amos (1975), Garson et al. (1976), Wolfart et al. (1984), Aye Ko Aung (2012) and Maung Thein (2014) were very remarkable. The intensive geological studies in the Pindaya area and its environs were carried out by Than Sein (1994) and Nandar Myint Maung (2004).

The eastern Pindaya range exposes thick Paleozoic shelf sequence, composed of Ordovician (the Wunbye and Nan-on formations of the Pindaya Group), Silurian (the Wabya and Linwe formations of the Mibayataung Group), Permina-Triassic (the Thitsipin Limestone and Nwabangyi Dolomite formations of the Plateau Limestone Group), and Cretaceous strata (the Kalaw Red Bed). The Permian Thitsipin Formation (Garson et al., 1976) was named after the Thitsipin village near Ye ngan town in southern Shan State.

This formation is composed of four informal rock units or facies of formation rank, bedded calcarenite, bedded or massive cherty limestone, massive limestone facies and thin-bedded, partly laminated, pale grey carbonates with numerous foraminifera, some gastropods, ostracods, corals, and shell debris in ascending order. This formation is sporadically exposed in several areas; e.g: the Kukaw village, near Choke Chack, and east of Thayetgon village.

The fossils reported in this report were collected along roadcuts in the Kukaw village and also near the Kyauk Sa Kyin village. They contain gastropods, rugose corals (*Lophophyllidium* spp., *Syringopora* spp., *Thomasiphyllum* sp., *Ipciphyllum* sp.), foraminifera (fusulinids? *Shanita* spp.), and thin-shelled and thick-shelled bivalves (Fig. 4-5). Although detailed age is still not contained; however, judging from the associated rugose corals, this formation is correlated with Permian, in particular, Guadalupian (Middle Permian).

Giant Clam Alatoconchidae

We found three sections of Alatoconchid-bearing succession in the western part of Pindaya Range (anticline) of Shan Plateau; i.e., one at 21° 15' 38.4"N, 96° 24' 58.9" E between mileposts 35/6 and 35/7 near Ye ngan Town, and the other two in Pindaya (Kukaw quarry at 20° 53' 04"N, 96° 37' 53"E and Choke Chack quarry at 20° 52' 27"N, 96° 38' 47"E). This article describes the best section among the three; the Kukaw section (Fig. 6) that exposes 9.25 m thick strata of the upper part of Thitsipin Formation with abundant gigantic bivalves.

At the Kukaw section, abundant alatoconchid shells are found on the cliff of quarry. This section starts from a 1.1 m thick brecciated dolomite at the bottom, which underlies the alatoconchid-bearing interval (ABI). ABI includes three distinct horizons with abundant alatoconchid; i.e., at 0.98 m in Bed 2, 1.77 m in Bed 6, and 1.8 m in Bed 11 (Fig. 7-8). Massive rugose corals (*Syringopora*), calcareous algae, gastropods occur in the ABI. Beds between the alatoconchid-bearing beds are composed of dolomite and dolomitic limestone with calcareous algae and also with foraminifer (fusuline?) fragments. Several slabs of brecciated dolomitic limestone and dolomites and 50 fragments of alatoconchid shells were collected in quarry scree (Fig. 9-10). Most of the shells are nearly 30 cm in length and about 10 cm width.

Discussion

The occurrence of Alatoconchidae from eastern Myanmar was confirmed for the first time in this study. This new evidence provides a solid clue to Paleozoic paleogeographic reconstruction of Asian blocks. Recent studies in southeast Asia clarified that East Sumatra, peninsular Thailand, eastern Myanmar, and western Yunnan (China) once formed an isolated continental block called Sibumasu (e.g., Metcalf et al., 2013; Cai et al., 2017), independent from Indochina block or South China block in the surrounding. The Sibumasu block was originated from the Gondwana margin probably next to India or Lhasa blocks. After the rifting from the Gondwana margin, it migrated to the north, and then docked to the South China margin during the Triassic time. The fusulines and conodonts from the Sibumasu block (e.g., Metcalfe and Kyi Pyar Aung, 2014) suggest that it was positioned in a low-latitude domain within the eastern Tethys during the late Paleozoic.

As summarized by Isozaki and Aljinovic (2009), the distribution of Alatoconchidae was highly limited to the Late Paleozoic low-latitude areas; i.e., Tunisia, Croatia, Oman (belong to the peri-Gondwana carbonate platform), Iran, Afghanistan, Malaysia, South China, and Thailand (from the Cimmerian Landmass), Japan, and Philippines (Fig. 11). The last two cases were recognized in accreted paleo-atoll limestones that were primarily positioned in the mid-Panthalassa. Additional occurrence was later reported from another accreted limestone in Alaska (Blodget and Isozaki, 2012). Thus the habitable area of the Permian Alatoconchidae extended over all low-latitude domains, including both the Tethyan and Panthalassa (Isozaki et al., 2006; Aljinovic et al., 2008) in accordance with associated warm-water biota, such as fusulines and rugose corals.

Conclusion

(1) This study clarified the first occurrence of the Permian large bivalve **Alatoconchidae gen. et sp. indet.** in Myanmar.

(2) During the Permian, the eastern part of Myanmar belonged to the Shibumasu Block located in low latitude domain between Paleo-Tethys and Panthalassa.

(3) The occurrence of Alatoconchidae from Myanmar is in accordance with the distribution of this unique bivalve family, restricted to the Permian tropical domains.

(4) In turn, they became extinct at the end of the Guadalupian together with large-tested fusulines (Verbeekinidae and Schwagerinidae) and a large variety of rugose corals (Waagenophyllidae).

(5) More detailed paleontological work is definitely required for the newly found unique large bivalves.

Acknowledgements

We would like to thank Acting Rector, Dr Aung Kyaw Thin and Pro-Rector, Dr Aye Aye Han, Banmaw University for allowing undertaking this research work. Professor, Dr Aung Khin Soe, Head of Geology Department, Banmaw University is grateful for his warm encouragement and providing necessaries at the department. We also grateful to Prof.

Shuzhong Shen, School of Earth Sciences & Engineering, Nanjing University, and Prof. Yichun Zhang, State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology for providing the valuable references.

References

Aljinovic, D., Isozaki, Y., Sremac, J. (2008). The occurrence of giant bivalve Alatoconchidae from the Yabeina zone (Upper Guadalupian, Permian) in European Tethys. *Gondwana Research* **13**: 275-287.

Amos, B.J. (1975). Stratigraphy of some Upper Paleozoic and Mesozoic carbonate rocks of the Eastern Highlands. *Newsletter of Stratigraphy* **4 (1)**: 49-70.

Aye Ko Aung, (2012). The Paleozoic stratigraphy of Shan Plateau, Myanmar-An updated Version. *Myanmar Geoscience Society* **5(1)**: 1-73.

Asato, K., Kase, T., Ono, T., Sashida, K., Agematsu, S. (2017). Morphology, Systematics and paleoecology of Shikamaia, aberrant Permian bivalves (Alatoconchidae: Ambonychioidea) from Japan. *Paleontological Research* **21 (4)**: 358-379. doi:10.2517/2017PR002.

Blodgett, R.B., Isozaki, Y. (2013). The Alataconchidae, giant Permian Tethyan bivalve family, and the first occurrence in Alaska (McHugh Complex of the Chugach Terrane) and the Western Hemisphere. *Alaska Geol*. **43**: 5–8.

Cai, F.L., Ding, L., Yao, W., Laskowski, A.K., Xu, Q., Zhang, J.E., Sein, K. (2017). Provenance and tectonic evolution of Lower Paleozoic-Upper Mesozoic strata from Sibumasu terrane, Myanmar. *Gondwana Research* **41**: 325-336.

Chen, F., Xue, W., Yan, J., Wignall, P.B., Meng,Q., Luo, J., Feng, Q. (2018). Alatoconchids: Giant Permian bivalves from South China. *Earth-Science Reviews* **179**: 147-167.

Garson, M.S., Amos, B.J. and A.H.G. Mitchell (1976). The geology of the area around Neyaungga and Ye ngan, southern Shan State, Burma. *Overseas, Mem. Inst. Geol. Sci.* London **2**:70p.

Isozaki, Y. (2006). Guadalaupian (Middle Permian) giant bivalve Alatoconchidae from a mid-Panthalassa paleo-atoll complex in Kyushu, Japan: A unique community associated with Tethyan fusulines and corals. *Proc. Jpn. Acad., Ser*. **B82 (1)**: 25-32.

Isozaki, Y., Aljinovic, D. (2009). End-Guadalupian extinction of the Permian gigantic bivalve Alatoconchidae: End of gigantism in tropical seas by cooling. *Palaeogeography, Palaeoclimatology, Palaeoecology* **284**: 11-21.

Maung Thein (2014). *Correlation table of the stratigraphic units of Myanmar*, Department of Geology, University of Yangon, 32p.

Metcalfe, I. (2013). Gondwana dispersion and Asian accretion: tectonic and palaeogeographic evolution of eastern Tethys. *Journal of Asian Earth Sciences* **66**: 1–33.

Metcalfe, I., Kyi Pyar Aung (2014). Late Tournaisian conodonts from the Taungnyo Group near Loi Kaw, Myanmar (Burma): implications for Shan Plateau stratigraphy and evolution of the Gondwana-derived Sibumasu terrane. *Gondwana Research* **26**: (1159–1172).

Nandar Myint Maung (2004). Geology of the Yegyanzin-Tale-in areas, Pindaya Township, southern Shan State, Unpublished MSc Thesis, Department of Geology, Dagon University, 73p.

Ozaki, K. (1968). Problematical fossils from the Permian Limestone of Akasaka, Gifu Prefecture. *Science Report* of *Yokohama National University, Section 2, Biological and Geological Sciences*, **14**: 27–33.

Than Sein (1994). Geology and sedimentology of the Paleozoic rock units of Yegyanzin area, Pindaya Township, Unpublished MSc Thesis, Department of Geology, University of Yangon, 123p.

Wolfart, R.U., Myo Min, Saw Boiteau, Myo Wai, Peter U K Chung, Thit Lwin (1984). Stratigraphy of the western Shan Massif, Burma. *Geologisches Jahrbuch* **B57**, Hannover, 92p.

A Study of Health Condition in Theinlin Village from the Aspect of Geology, Banmaw Township

Kyi San Lin[1], Su Su Aung[2], Zar Zar Lynn[3]

Abstract

The research area is around the Theinlin Village, 4 miles south of Banmaw. The study area is situated between latitude 24˙ 00′ N to 24˙ 30′ N and longitude 97˙ 00′ E to 97˙ 30′ E respectively in one inch topographic map index 92 H/4. The study area is situated nearly south of the Banmaw plain. The study area, Theinlin Village, is mainly composed of Quaternary alluvial sediments. The alluvium sediments are sandy clay and silty clay. Most of the farms are cultivated on this alluvium plain. The water samples were collected from different four sources to know the water qualities related with health. Samples (1, 3 and 4) are satisfactory to use as drinking water. But sample 2 is not clean and safe due to the presence of high content of turbidity and conductivity. The common diseases in villagers are Hypertension, Diabetes and other complication such as Malaria. Therefore, the most common disease found in villagers was not related to geology condition of the study area. But we would like to suggest the villagers that not to birth mosquitoes, wastes should be properly disposed of and the construction of drainage channels, ponds and wells are provided with a shelter and insulated with water from contamination, avoid foods that are too salty and sweet, and food should be eaten in a balanced way.

Keywords: Regional geology, Quaternary alluvium, Hypertension, Diabetes, Malaria

Introduction

The research area is around the Theinlin Village, 4 miles south of Banmaw Township. The study area is situated between latitude 24˙ 00′ N to 24˙ 30′ N and longitude 97˙ 00′ E to 97˙ 30′ E respectively in one inch topographic maps index 92 H/4. The study area, Theinlin Village, has about 450 houses and over 2000 villagers live there. Most of them are Shan people and practice Buddhism. Banmaw-Shwegu car road passes through near the study area. So, the study area can be reached by car the whole year. The location map of the study area is shown in (Fig-1.1).

Materials and Methods

As conventionally done in regional mapping, both field and laboratory methods were applied in studying the research area. By studying the topographic and satellite maps, some notably features can be learnt. The field works were carried out on weekend and holidays. Physicochemical parameters of water were measured at the water laboratory, Water and Sanitation Department, Mandalay City Development Committee and Department of Chemistry, Banmaw University. Appropriate methods are used to obtain data necessary for

1 Associate Professor, Department of Geology, Banmaw University
2 Dr, Associate Professor, Department of Chemistry, Banmaw University
3 Tutor, Nursing Training School(Banmaw)

community diagnosis and applied basic knowledge from selected disciplines in the understanding of the community health.

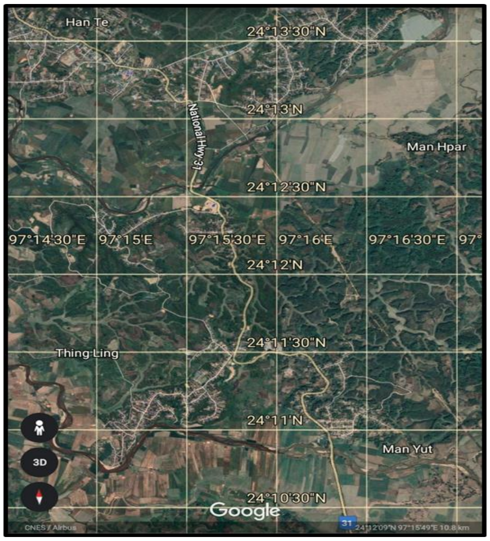
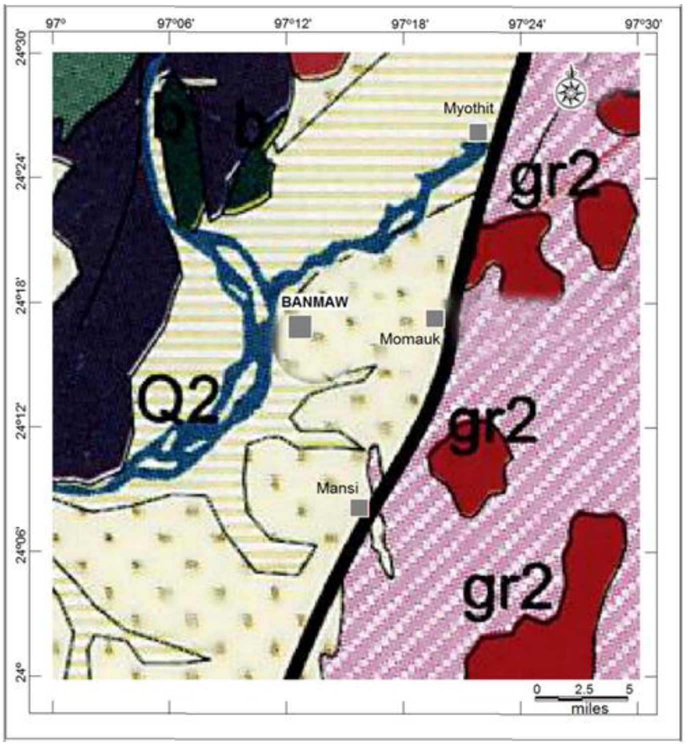


Fig. (1) Location map of the study area

Regional Geologic Setting

Regional geologic setting of the study area and its environs were studied from one million scale map. Bender (1983) stated that at the Sino-Burma ranges, east of the Shan Boundary Fault Zone were cropped out consolidated Precambrian, Paleozoic and Mesozoic sediment sequences. This belt extends southward through the Shan Plateau and Tanintharyi ranges and northward to the Eastern Himalayas and Yunnan Province of China. The research area lays in the northern eastern part of the Eastern Highland (Shan Tanintharyi Block or Shan-Thai Block).

The Eastern Highland is composed of the variety of rocks ranging in age from Precambrian to Cenozoic. The regional geologic setting of the study area is mostly composed of Cretaceous Ophiolite assemblage, igneous rocks and Quaternary alluvial sediments. The study area is situated nearly south of the Banmaw plain. The study area, Theinlin Village, is mainly composed of Quaternary alluvial sediments.Regional geological map of the study area is shown in Figure (2).



Explanation

Q2	Holocene	Younger Alluvium	
Q1	Pleistocene	Older Alluvium	
gr2	Mesozoic and Lower Tertiary	Granitoids – granite, granodiorite, diorite, and non-basic intrusives; locally transformed into granite gneiss and metadiorite	
b	Mostly Jurassic	Gabbro and related rocks	
ub	Mostly Jurassic	Ophiolite assemblages – serpentinites, pyroxenites, peridotites, gabbro and pillow lavas	
m1	Paleozoic, and partly Jurassic	Metamorphosed units of mainly Lower Paleozoic rocks – Mogok Metamorphic Belt and its extensions: Mogok Group (Pz); Eastern Kachin metamorphics	

Fig. (2) Regional Geological Map of the Study Area (Source; MGS, 2014)

Distribution of Rock Units

The plateau gravels are made up of coarse grain material deposited by probably ancient stream channel. Now, these areas are far from the present coarse stream and at high above level. Large deposits of the plateau gravels are found as isolated mounds. Deposits are composed of gravel and medium to coarse grain sands is thickness in vary from 3ft to 30ft with high yield. The" Plateau Gravels" of pebbles averaging half or one inch in diameter, and are loosely aggregated in red ferruginous sand (Fig.3).

Alluvium unit consists of silty clay (Fig.4) and sandy clay (Fig.5).The newer alluvium building up the banks of Theinlin Chaung. The composition of the sand or gravel varies with the locality. Coarse gravels are generally overlain by the clay, and exposed only where it is cut through an excellent example being seen in the gentle cliff of the study area. Here, the clay is about 3 feet in thickness, and its surface is not less than 10 feet above the flood level of the

Theinlin Chaung. Two or three inches may be taken as the average size of the large and more plentiful ones, but a few larger ones than those also occur. The cultivated fields are well developed on the alluvium plains (Fig.6).The Theinlin Chaung gives rise to fertilizer for the crops growing land along the banks of this stream.

Fig. (3) Plateau gravel unit

Fig. (4) Silty clay of the alluvium unit

Fig. (5) Sandy clay of the alluvium unit

Fig. (6) Cultivated area of the study area

Collection of Water Samples

Water samples were collected from sampling sites (1, 2, 3 and 4) (Table.1) in March, 2020 (Figure-7). Sample collection and testing of water qualities were continuously made within 24 hours.

Table (1) Water samples locality

No.	Sample No.	Locality	Source
1	Sample (1)	24˙11′ 11.322″ N and 97˙15′ 19.314″ E	Artesian Well
2	Sample (2)	24˙11′ 10.242″ N and 97˙15′ 18.671″ E	Artesian Well
3	Sample (3)	24˙11′ 02.250″ N and 97˙15′ 18.732″ E	Theinlin Chaung
4	Sample (4)	24˙11′ 07.361″ N and 97˙15′ 10.577″ E	Well

Water Analysis

Based on physicochemical parameters, an evaluation was made to determine the extent of water quality.The physicochemical parameters of the samples are shown in (Table.2).

In the present work, the water samples were collected from different sampling sites (1, 2, 3 and 4) in March 2020. Standard methods were used for determining of chemical and physical characteristics of the four water samples.

From the above experimentation, it was observed that among the four water sampling sites, water analysis was carried out; maximum (pH 7.1) was recorded in sampling site (2), whereas minimum (pH 6.8) was observed in sampling site (1, 3 and 4). According to the pH ranged between 5.0 and 8.5 is best for planktonic growth.

For all the forms of aquatic life dissolved oxygen (DO) is essential component to break down man-made pollutants. The presence of dissolved oxygen is essential to maintain the higher forms of biological life and to keep proper balance of various pollutions and thus, making the water bodies healthy. The chemical and biological process undergoing in water body are largely dependent upon the presence of oxygen. Estimation of dissolved oxygen is a key test in water pollution and waste treatment process control. In this present investigation, Maximum DO (7.76 mg/L) was recorded in sampling site (3), whereas minimum DO (7.70 mg/L) was recorded in sampling site (2). DO level of the WHO guideline for surface water, ground water and aquatic life is 3.0-6.0 mg/L.

Turbidity is a measure of light transmission and indicates the presence of suspended material (clay, slit, finely divided organic material, plankton and other inorganic material). If turbidity is high, be aware of possible bacterial contamination. Maximum (31 NTU) was observed in sampling site (2), whereas minimum (0.63 NTU) was observed in sampling site (1). The sampling site (2) was greater than WHO standard (5-20 mg/L) of drinking water.

Table (2) Physicochemical Analysis of Different Sampling Sites

No	Parameters	Sampling Sites				WHO standard	
		1	**2**	**3**	**4**	**Desirable**	**Imperative**
1	pH	6.8	**7.1**	6.8	6.8	7-8.5	6.5-9.2
2	Colour	5	>50	>50	5	5	50
3	Turbidity(NTU)	0.63	**31**	4.34	0.93	5	25
4	Conductivity(μS/cm)	219	**305**	74.7	193.6	-	-
5	Ca(ppm)or mg/L	16	32	10	8	75	200
6	Hardness, Total $CaCO_3$ (mg/L)	64	**120**	48	24	100	500
7	Mg(ppm)or mg/L	5	10	6	1	30	150
8	Cl (ppm)or mg/L	**30**	5	5	20	200	600
9	Total alkalinity	28	**180**	48	24	200	500
10	Fe(ppm)or mg/L	0.01	>0.2	>0.2	0.01	0.1	1.0
11	Mn(ppm)or mg/L	0.01	0.03	0.03	0.01	0.05	0.5
12	SO_4^{2-}(ppm)or mg/L	<200	<200	<200	<200	200	400
13	DO(ppm)or mg/L	7.64	7.70	7.76	7.63		
14	Total Dissolve Solid(ppm)or mg/L	0.36	0.36	0.37	0.37		

Conductivity is the ability of an aqueous solution to conduct the electric current. Water becomes a conductor of electrical current when substances are dissolved in it and the conductivity is proportional to the amount of dissolved substance. Maximum conductivity (305 μS/cm) in sampling site (2), whereas minimum conductivity (74.4μS /cm) was recorded in sampling site (3). The source of CD may be an abundance of dissolved salts due to poor irrigation management, minerals from rain water runoff or other discharges.

The alkalinity of water is necessary for controlling the corrosion of the boiler feed water. In boilers for steam generation, high alkalinity of water may not only lead to caustic embrittlement but also to the precipitation of sludge and deposition of scales. Maximum value of total alkalinity (180 mg/L) was recorded in sampling site (2), whereas minimum value of total alkalinity (24 mg/L) in sampling site (4). These results are less than the WHO standard value (200 mg/L).

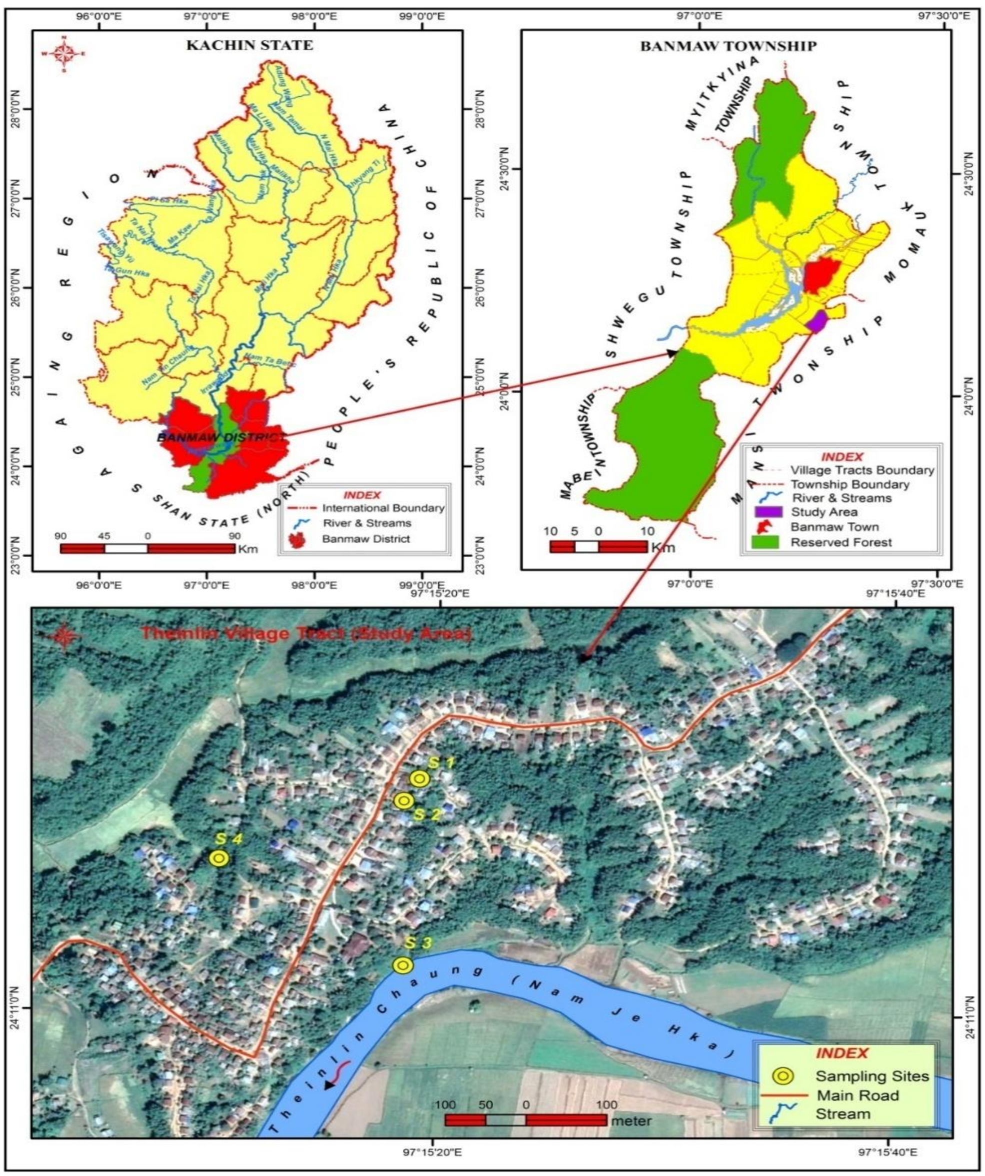


Figure (7) location and water samples sites of the study area

Total dissolved solid mainly denote the various kinds of minerals in water. There is no gas and colloids in TDS. Maximum TDS (0.37 mg/L) was recorded in sampling site (3, 4), whereas minimum TDS (0.36 mg/L) in sampling site (1,2).

In total hardness, maximum TH (120 mg/L) was recorded in sampling site (2), whereas minimum TH (24 mg/L) in sampling site (4). These results are limiting range of the WHO standard value (100-500 mg/L).

From the above experimentation, maximum chlorinity (30mg/L) was recorded in sampling site (1), whereas minimum chlorinity (5 mg/L) in sampling site (2).

After water treatment from Industrial Chemistry Laboratory, the pH ranges of all sampling sites were within WHO standard (6.5-8.5). The results of dissolved oxygen, turbidity, conductivity, total alkalinity, total dissolved solid, total hardness and chloride content of the four sampling sites were decreased the original samples data respectively.

The concentrations of TDS were observed in the range of (-) ppm. The standard WHO is < 600 ppm. In the case of Ca^{2+}, Mg^{2+}, Fe^{2+}, Mn^{2+}, SO_4^{2-} , these are very much lower than allowable limit of WHO.

The resulting findings indicated that the water body of the study area may not be clean and safe due to the presence of high contents of turbidity and conductivity in sample (2) due to significant features of microbiological species.

To make pollution free, waste water management and monitoring systems should be established. To give more comprehensive and better representation of water quality of the study area, further studies should be made with respect to more sample collection sites, sampling period and other water quality parameters. So, they were standardizing with WHO standard from the chemical and physical points of view. The water samples (1,3and 4) are satisfactory because all parameters are agree with the WHO standard. So, the three water samples are to use as drinking water.

Health condition of the Study Area

There are 1070 males and 1106 females in Theinlin Village and the sex ratio is 96.75%. The age ratio of 0-14 is 26%, of 15-59 is 66% and of above 60 is 8% respectively. The health data were collected from each family of the study area, Theinlin Village. The village roads were uneven and the puddles and potholes were unevenly flowing. Drinking water and domestic water are obtained from artesian well, Theinlin Chaung and well. Drinking water is not commonly used for boiling. Most of the villagers had poor healthy knowledge. Mosquitoes are abundant because grasses and shrubs are not clear. The common diseases in villagers are Hypertension, Diabetes and other complication such as Malaria. The most common diseases in villagers are scabies, anaemia and malaria which is about 60%. The second most common disease is communicable disease which is about 16%. And the third is hypertension which is about 10%. The last common disease is Malnutrition which is about 6%.

Discussion

High prevalence rate of communicable disease (DHF, Malaria) related to presence of mosquito breeding areas, insects and rodents as manifested by 16% of communicable disease. Poor environmental sanitation related to improper refuse disposal and improper drainage system as manifested by 100% of improper drainage system. Polluted water supply related to presence of harbor of mosquitoes and larvae as manifested by 50% Malaria.

Hypertension related to faulty eating habits as manifested by 10% of people suffering in ten houses. Malnutrition related to inadequate food intake both quality and quantity as manifested by 6% of malnutrition.

Therefore, the most common causes of villager' disease are improper refuse disposal and drainage system, polluted water supply, high prevalence rate of communicable disease, hypertension and malnutrition.

Conclusion

The research area is around the Theinlin Village, 4 miles south of Banmaw Township. The study area, Theinlin Village, has about 450 houses and over 2000 villagers live there. The study area is situated nearly south of the Banmaw plain.

The study area, Theinlin Village, is mainly composed of Quaternary alluvial sediments. The alluvium sediments are sandy clay and silty clay. Most of the farms are cultivated on this alluvium plain.

The water samples were collected from different four sources to know the water qualities related with health. Samples (1, 3 and 4) are satisfactory to use as drinking water. But sample 2 is not clean and safe due to the presence of high content of turbidity and conductivity.

The common diseases in villager are Hypertension, Diabetes and other complication such as Malaria. Therefore, the most common diseases found in villagers were not related to geology condition of the study area.

We would like to suggest the following to alleviate the suffering of the villagers.

1. To reduce the high prevalence rate of communicable disease (DHF, Malaria), avoid the emergence of moth larvae by clearing shrubs and clearing the watershed

2. To reduce the poor environmental sanitation, waste should be properly disposed of and the construction of drainage channels

3. To reduce the polluted water supply, Ponds and wells are provided with a shelter and insulated with water from contamination

4. To prevent high bold pressure, avoid foods that are too salty and sweet. Also, if you have hypertension, you need to measure your weight regularly and take your doctor's prescription medication regularly

5. To reduce the malnutrition, food should be eaten in a balanced way

References

Bender, F., (1983).*Geology of Burma*, Gebrunder Borntraeger, Berlin. 293p.

Chhibber, H.L. (1934). *The Geology of Burma*. MacMillan & Co., London, 538 p.

Second Year Students, (Nursing Training School, Banmaw), (2016). *Community as a Client, Theinlin Village, Banmaw Township.* Report Paper

Dr Sandar Win, U Tun Tun Saw, U Kyi San Lin, Daw San San Win, Daw Khaing Khaing Maw, (2017). *Geology of Sinkham and Zinbon Area, Shwegu Township, Kachin State.* Departmental Research Paper

World Health Organization, (1993). *Guidelines for Drinking Water Quality*, Geneva, Switzerland, 25.

မောင်ကျေးရေ (ဦးမြင့်သိန်း), ၂၀၁၀. *မြေအောက်ရေနှင့်ရေအရေးစာစုများ,*စိတ်ကူးချိုချိုစာပေ, (၀၀၅၃၈)၊ ၈၅၊ ၁၆၄ လမ်း၊ တာမွေ၊ ရန်ကုန်.

Study on the Genetic Model of Polymetallic Epithermal Quartz Veins at Soripesa Prospect Area, Sumbawa Island, Indonesia

Win Khant*

Abstract

The Soripesa prospect area is located at Maria village, Wawo district, Bima regency, East Sumbawa, Indonesia. The Sumbawa Island forms as a part of the west-east trending Cenozoic calc-alkaline volcanic inner Sunda-Banda magmatic Arc. Soripesa prospect area is mainly occupied by lava and breccia of andesitic and basaltic composition, bedded fossiliferous limestone, dacitic lava and breccias. The main quartz veins are Jambu Air vein, Arif vein, Rini vein, Dollah vein, and Merpati vein. Those quartz veins are hosted in andeisitic volcaniclastic rock unit. SEM-EDX, XRD, and fluid inclusion studies are used in this research. Based on the Fe mole %, sulfur activity (a_{s_2}) is a little higher and between 10^{-10} – 10^{-11}. Ga/Ge ratios of sphalerites indicate that the formation temperatures of sphalerite are between 180°C and 240°C. Sulfur activity and formation temperature plots show the intermediate sulphidation state of epithermal system. Fluid inclusions data show that Plots of T_h and salinity of quartz vein, generally, show the trends of boiling processes. Estimated paleodepth of formation of quartz veins are around 270 to 550 m based on formation temperature and salinity using boiling curve point. Fluid flow direction can be assumed from Jambu Air vein to Merpati vein. Jambu Air vein is formed at the lower part of vein system and Merpati vein formed at the upper part of system.

Keywords: Epithermal, alteration minerals, ore minerals, fluid inclusion, formation temperature

Introduction

The Soripesa prospect area is located in Maria village, Wawo district, Bima regency, eastern Sumbawa Island, Indonesia (Fig. 1). Some active volcanoes are found in Sumbawa islands. The research area is previously owned by PT. Bima Baruna Raya Mining (BBRM) and PT. Sumbawa Timur Mining. Those mining companies carried out some geological works in this research area. At the present time, the PT Bima Putera Minerals (Indomining Group) already had a Mining permit for the deposit at the Soripesa prospect area. This area had been observed to have Au-Ag deposits and base metal mineralization. Ore mineralogy consists of chalcopyrite, azurite, malachite, sphalerite, galena and pyrite forming as epithermal quartz veins. This region is seismically active and located about 230 km northeast of Batu Hijau Porphyry Cu-Au deposit. Therefore, **the prospectively of Bima is further enhanced** by the fact that the project lies in the same segment of magmatic arc.

* Dr, Associate Professor, Department of Geology, Banmaw University

Town and village River and stream Motor road Volcano

Soripesa prospect area

Figure 1. Location map of the Soripesa prospect area.

Regional Geology

The Sumbawa Island forms as a part of the Cenozoic calc-alkaline volcanic inner Sunda-Banda Arc. The East Sumbawa area is largely underlain by andesitic to basaltic lava and breccia of the Early Miocene, with intercalations of tuff and limestone, and fresh pyroclastic sequences (Noya *et al*., 2009). The Soripesa prospect area is mainly occupied by lava and breccia of andesitic and basaltic composition; intercalation of andesitic tuff and crystalline limestone (Old Volcanic Rock Unit) (Noya *et al.*, 2009). It is unconformity overlain by bedded limestone and tuffaceous sandstone (Limestone Unit). Laterally, the Formation changed into pyroclastic rocks (breccia) with mostly dacitic in composition (Volcanic Rock Unit). The geological map of the Soripesa area is shown in Figure 2.

Old Volcanic Rock Unit (Early Miocene)

This rock unit is composed of lava and breccia of andesitic and basaltic composition. These rocks are commonly greenish grey, green and violet for the intercalation of tuff. The rocks are propylitized, mineralized, and silicified contain quartz veins. In Soripesa prospect area, this rock unit mainly occur in central part of the area. Economically, this unit is important and polymetallic epithermal quartz veins are hosted in this unit.

Explanation

Figure 2. Geological map of the Soripesa prospect area (modified after Noya *et al.*, 2009).

Limestone Unit (Miocene)

In this unit, bedded limestone is the main lithology. It is grey, compact, and some layers contain abundant fossils. The rocks contain a lot of fauna such as foraminifera, coral, and mollusc. Limestone unit are found in small amount near Soripesa river and central part of the prospect area. This unit may be formed at Early Miocene to Middle Miocene (Tertiary) in age.

Volcanic Rock Unit (Middle Miocene)

This unit comprises dacitic lava and breccias, commonly grey, and compact. These rocks contain intercalations of dacitic tuff and calcareous tuff. Petrographic determination shows that the rocks consist of dacite and porphyritic dacitic that locally contains many quartz veins. The rocks are silicified and mineralized in place. This rock unit mainly occurs in western and southern part of the prospect area.

Lahar and Agglomerate Rocks Unit (Quaternary)

Andesitic and dacitic volcaniclastic rocks are unconformably overlain by Quaternary lahar and agglomerate rocks, with basaltic to andesitic in compositions. These rocks are product of Maria volcano and are mostly exposed at the northern side of the prospect area. Recently, Maria volcano is an inactive volcano. This rock unit may not be related with the quartz veins and mineralization in this research area.

Research Methods

Scanning Electron Microscopy with Energy-Dispersive X-Ray Analysis (SEM-EDX)

For SEM-EDX analyses, 15 polished sections and 3 thin sections were used to identify mineral chemistry by using a SHIMADZU SS-550 SEM with a Genesis 2000 energy dispersion spectrometer (EDX) at the Center of Advanced Instrumental Analysis, Kyushu University. Some ore samples such as sphalerite, galena, pyrite were analyzed by SEM-EDX for elemental identification and compositional information.

Fluid Inclusion Study

Selected 5 quartz samples from 5 main veins were analyzed for fluid inclusion study at the Department of Earth Resources Engineering and Research Institute of Environment for Sustainability, Kyushu University, Japan. All of the fluid inclusion investigations have been performed on the host quartz minerals. For fluid inclusion study, samples were made double polish sections and the slice thicknesses are approximately between 100 to 200 µm. At least about 50 fluid inclusions were measured for one sample. Therefore, over 250 fluid inclusions were measured to get microthermometric data, especially, homogenization temperature and melting temperature. Microthermometry of fluid inclusions was conducted in terms of heating experiments using a USGS adopted fluid inclusion heating stage and also using a heating stage (Linkam microthermometry unit LK-600PM) and freezing stage (Linkam microthermometry unit LK-600A).

Results and Discussion

Sphalerite Geothermometry

A very interesting recent development is the Ga/Ge geothermometer using sphalerite (Möller, 1985). Ga/Ge can be used to determine temperatures in the source regions of ore solutions and to estimate the degree of mixing of hot parental ore fluids with cool, near surface waters (Evans, 1993). 10 samples were simultaneously detected levels for these two elements. The application of these geothermometer results of calculating the logarithm follows:

$$\log [(Ga/Ge)\ f] \equiv \log [(Ga/Ge)\ sph]$$

Note that: f - mineraliser fluid; sph - sphalerite.

Determining the values of log (Ga/Ge) for the analyzes of sphalerite minerals, we obtain the values in the ranges between -0.4 to 1.15. These values are applied to the chart geothermometer Ga/Ge. The chart shows the values of temperatures between 180°C to 240°C. Figure 3 presents the projection of the respective analysis chart that correlates the race Ga/Ge with the temperature. This graph is based on geothermometers known systems of Al/Si and published data for reasons of Ga/Ge in many geological systems (Möller 1985, 1987).

Figure 3 Graph showing the dependence between Ga/Ge ratios in sphalerite and formation temperature. This graph is based on existing Al/Si geothermometers. The musc-chlo-qtz line is the chlorite geothermometer in the Si/Al system (Möller, 1985, 1987).

Sulphur Activity and Sulphidation State

Kullerud (1953) suggested that the FeS content of sphalerite gave a direct measurement of its temperature of deposition. Average Fe content (1.04%) of sphalerite in this research is very low. Mole % FeS in sphalerite is also very low and between 1 – 2%. In Zn-Fe-S of low pressure system, this value (1-2%) falls in pyrite+chalcopyrite field (Fig. 4).

Figure 4. Phase relationships for the Fe-Zn-S system at 1 bar compiled from Scott and Barnes (1971). Red line represent sulfur activity of sphalerite from Soripesa prospect area. Abbreviations: bn=bornite; cpy=chalcopyrite po=pyrrhotine; py=pyrite; S*l*=liquid sulphur; S*v*=sulphur vapour.

Within the pyrite field, the decrease in FeS content of sphalerite with increasing sulphur activity (a_{s_2}) is much greater resulting in a close spacing of isopleths near the pyrite-pyrrhotite buffer and in very low FeS contents in sphalerite at high sulphur activity ($a_{s_2} \approx 10^{-9} - 10^{-11}$). It is commonly found that sphalerites formed at high a_{s_2} have a honey yellow to light brown colour with their low FeS contents whereas sphalerites formed at low a_{s_2} and within the pyrrhotite field are dark brown to black (Scott, 1983). Based on sulphur activity and temperature, it indicates that plots are fallen in intermediate sulphidation state, pyrite+chalcopyrite field, and magmatic hydrothermal compositional field (Fig. 5).

Figure 5. f_{s_2}–*T* diagram showing the variety of sulfide assemblages in epithermal deposits that reflect sulphidation state from very low through low and intermediate to high and very high. (Sillitoe and Hedenquist, 2003).

Fluid Inclusion Study

Microthermometry

Microthermometry analysis will allow estimating the temperature of homogenization and temperature of melting. According to the histograms of homogenization temperature, the formation temperature of Merpati Vein is between 210°C and 220°C, Dollah Vein is 230-240°C, Rini Vein is 240-250°C, Arif Vein is 250-260°C, and Jambu Air Vein is 260-270°C, respectively. Average melting temperature of each vein is -1.88°C for Merpati vein, -1.43°C for Dollah vein, -0.93°C for Rini vein, -1.13°C for Arif vein, and -1.08°C for Jambu Air vein, respectively. Melting temperature is very important for calculating the salinity using Bodnar’s equation. The average salinities (wt.% NaCl equiv.) of the fluid for quartz veins are 3.15 for Merpati vein, 2.44 for Dollah vein, 1.6 for Rini vein, 1.95 for Arif vein, and 1.86 for Jambu Air vein, respectively. Homogenization temperatures are also very useful for estimating the deposits types, formation temperature, density, fluid evolution processes, trapping pressure, and paleodepth.

Salinity Determinations

The fluid inclusion salinity (% NaCl equiv.) is calculated based on the melting temperature and by using Bodnar's equation (1993). The average salinity of the fluid for all veins is 3.15 for Merpati vein, 2.44 for Dollah vein, 1.6 for Rini vein, 1.95 for Arif vein, and 1.86 for Jambu Air vein, respectively (Table 1). Salinity of fluid is also very important to know the fluid evolution processes, density of fluid, depth of formation, and pressure of trapping, and so on. Based on the homogenization temperature ranges (182-300) and average salinity (0 – 5 wt.% NaCl equiv.), polymetallic quartz veins are sure to form under epithermal system. Salinity variations can be produced by boiling or effervescence, but significant salinity increases will only occur by continuous boiling in restricted fractures (Wilkinson, 2001). Significant salinity variations are most likely to be controlled by fluid mixing, except where dissolution of evaporates can be demonstrated.

Table 1. Results for T_h, T_m, and Salinity (wt.% NaCl equiv.) determination in fluid inclusions from quartz veins at Soripesa prospect area, Sumbawa Island.

Veins	T_h ranges	Average T_h	T_m ranges	Average T_m	Average Salinity
Merpati vein	182-279	224	-3.0 – -0.3	-1.88	3.15
Dollah vein	212-300	248	-2.6 – -0.5	-1.43	2.44
Rini vein	185-266	239	-1.8 – -0.2	-0.93	1.60
Arif vein	216-300	256	-2.0 – -0.6	-1.13	1.95
Jambu Air vein	233-297	263	-2.0 – -0.3	-1.08	1.86

Paleodepth and Pressure of Trapping

The formation temperature estimated from fluid inclusion microthermometry can be used to infer formation depth of veins using the boiling point curve of Hass, 1971 (Shepherd, 1985). According to plots of T_h and Salinity values, estimation paleodepths of formation are 270m for Merpati vein, 360 m for Rini vein, 410 m for Dollah vein, 500 m for Arif vein, and 550 m for Jambu Air vein. The paleodepths of veins are different based on the different formation temperatures. The results for the depths of formation of five veins are shown in Figure 6.

Figure 6. Estimation of the average minimum formation depth of the Polymetallic epithermal quartz veins at Soripesa prospect area using the boiling point curve with formation temperature and salinity (Haas, 1971).

Genetic Model for the Development of Epithermal Quartz Veins

Based on the formation temperature, salinity, paleodepth, fluid evolution processes, and sulphidation state, the genetic model for the development of epithermal quartz veins can be constructed. Firstly, because of subduction, magmatic source may appeared under andesitic-dacitic rock sequence (Fig. 7A). Combination of magmatic fluid and meteoric fluid may form a zone of potential intermediate sulphidation epithermal gold deposition. In general, Jambu Air vein and Arif vein are formed in the early stage. Rini vein and Dollah vein are formed in the middle stage. Merpati vein is formed in the last stage.

In the first stage, Jambu air vein and Arif vein are formed at temperature (average 263°C and 256°C) and a little higher temperature than other veins (Fig. 7B). But, average salinity of Jambu Air vein and Arif vein are lower than other veins. Salinity trends of these veins shows boiling (low salinity) processes and cooling processes. Paleodepths of these veins are also higher than other veins' paleodepth. Therefore, Jambu Air vein and Arif vein have higher formation temperature, higher paleodepth, lower salinity than other veins. In the second stage, Rini vein and Dollah vein are formed at paleodepth of about ≈400 m with average formation temperature of 239°C and 248°C (Fig. 7C). Average salinity of Rini vein is 1.6 wt.%

NaCl equiv. and 2.44 wt.% NaCl equiv. for Dollah vein. Salinity trends show their fluid evolution processes. In this stage, the paleosurface will be gradually uplifting.

In the last stage, Merpati vein has formed near surface and approximately, at the paleodepth of ≈270 m with formation temperature of 224°C. Average fluid salinity is about 3.15 wt.% NaCl equiv. and higher than other veins. Salinity trend shows the fluid boiling processes. Merpati vein indicates the decreasing pH conditions and decreasing temperature. Finally, upper part of the paleosurface is weathering and eroded. After weathering and eroding, current surface has appeared with epithermal quartz veins (Fig 7D). Figure 13 shows the development of epithermal quartz vein at Soripesa prospect area, Sumbawa island.

Figure 7. Genetic model for the development of intermediate sulphidation epithermal quartz veins at Soripesa prospect area, Sumbawa island, Indonesia (modified after Sillitoe and Hedenquist, 2003; Bogie *et al*., 2005). A. Initial state of magmatic intrusion at volcanic edifice. B. Forming the zone of potential for intermediate sulphidation deposits near faults. C. Intermediate sulphidation Au-Ag veins are formed along the faults within mineralization zone. D. After uplifting and eroding the surface, quartz veins are occurred on the current surface.

Conclusion

1) Low content of Fe, high content of Ga and Ge, also indicate that sphalerites from this research are formed in low temperature of quartz veins. Formation temperatures of those sphalerite are between 180°C and 240°C. Sulfur activity and formation temperature indicate that their plots are fallen in the field of intermediate sulphidation state of epithermal system and magmatic hydrothermal compositional field. Therefore, it can be concluded that epithermal quartz veins at Soripesa prospect area are formed under the intermediate sulphidation epithermal system.
2) Microthermometry results can be used to estimate formation temperature of the deposit and salinity of the responsible hydrothermal fluid. Formation temperatures of all veins are between 180°C and 300°C. Salinity of ore forming fluid of all veins are also very low and

between 0 – 4 NaCl equiv. The above factors shows that all veins are formed under the condition of epithermal system.

3) Based on the genetic model, these fluid flow directions can be assumed from Jambu Air vein to Merpati vein. Jambu Air vein is formed at the lower part of vein system and Merpati vein at the upper part of system.

Acknowledgement

The author want to express deep thanks to Dr. Aung Kyaw Thin, Rector and Dr. Aye Aye Han, Pro-Rector, Banmaw University, for their kind permission to submit this research paper. The author also thanks Dr. Aung Khin Soe, Professor/Head, Department of Geology, Banmaw University for his encouragement and suggestions. The author wishes to thank Earth Resources Engineering Department, Kyushu University for performing laboratory works and analyses.

References

Bogie, I., Lawless, J.V., Rychagov, S., and Belousov, V., (2005), Magmatic-related Hydrothermal System: Classification of the Types of Geothermal Systems and Their Ore Mineralization. Material Field Seminar Kuril-Kamchata, July 16 – August 6, (2005), p. 51-73.

Bodnar, R.J., (1993), Revised equation and table for determining the freezing point depression of H2O-NaCl solutions: *Geochimica et Cosmochimica Acta* Vol, 57, pp. 683-684.

Evans, A.M., (1993), *Ore Geology and Industrial Minerals: An Introduction*, Blackwell scientific publications, 3rd edt., 390 p.

Haas, J.L., (1971), The Effect of Salinity on the Maximum Thermal Gradient of a Hydrothermal System at Hydrostatic Pressure, *Economic Geology*, Vol. 66, pp. 940-946.

Kullerud, G., (1953), The FeS-Zns system: a geological thermometer. *Nor. Geol. Tiddskr*., Vol. 32, p. 61-147.

Möller, P., (1985), Development and application of the Ga/Ge-Geothermometer for sphalerite from sediment hosted deposits, In Germann K. (ed.), *Geochemical aspects for Ore Formation in Recent and Fossil Sedimentary Environments*", pp.15-30.

Möller, P., (1987), Correlation of Homogenization Temperatures of Accessory Minerals from Sphalerite-bearing Deposits and Ga/Ge Model Temperatures, *Chemical Geology*, Vol.61, pp, 153-159.

Noya, Y., Effendhy, O., Hamdan Z., Abidin, and Pakaya, Y., (2009), Geological background and economic prospect of the Soripesa deposit, east Sumbawa. Proceeding PIT IAGI Semarang,(2009).The 38th IAGI annual Convention and Exhibition Semarang.

Scott, S.D., (1983), Chemical behavior of sphalerite and arsenopyrite in hydrothermal and metamorphic environments Mineralogical Magazine, vol.47, pp.427-435.

Scott, S.D., and Barnes, H.L, (1971), Economic Geology, Vol.66, pp. 653-669.

Shepherd, T.J. (1985), *A Practical Guide to Fluid Inclusion Studies*, Balckie, 237 p.

Sillitoe, R.H.,and Hedenquist, J.W., (2003), Linkages between Volcanotectonic Settings, Ore-Fluid Compositions, and Epithermal Precious Metal Deposits. Society of Economic Geologists, Special Publication, 10, p. 315-343.

Wilkinson, J.J., (2001), Fluid inclusions in hydrothermal ore deposits. Elsevier Science, *Lithos* 55 (2001), 229–272.

Petrography and Petrogenesis of Metamorphic Rocks Exposed in the Thetkegyin Area, Patheingyi Township, Mandalay Region

Khaing Mar Oo[1] and Shwe Nan Wai[2]

Abstract

The study area is situated about 12 km north-east of Patheingyi Township, Mandalay Region. The area under the present investigation forms part of the highly deformed metamorphic rocks of so called Mogok Metamorphic Belt (MMB). The research work focused on the petrography and petrogenesis of metamorphic rock of the study area. The main rock units are phlogopite marble, diopside-phlogopite marble, calc-silicate rock, staurolite schist, quartzite, sillimanite schist, and garnet schist. These rocks mainly show granoblastic texture, porphyroblastic texture and schistose texture. According to the occurrence of the mineral assemblages, lower- to upper-amphibolite facies and medium to high grade regional metamorphism are observed. The age of the metamorphic rocks of the study area is assumed to be contemporaneous with the Mogok Metamorphic Belt on the basis of lateral continuity and lithologic similarities and presented here confirm the early Paleozoic age.

Introduction

The study area is situated about 12 km north-east of Patheingyi Township, Mandalay Region. The present area lies between Latitude N 22° 04' 15" - 22° 09' and Longitude E 96° 11' 17" - 96° 13' 20" (Fig 1). It is located between N-S grids (76-85) and E-W grids (70-80) and is covered by one-inch topographic maps 93/B4 & 93/B8. It extends for about 5.4 km in N-S direction and 4.5 km in E-W direction and covers an area extent of approximately 24.3 square kilometers. Petrologically, the Thetkegyin area should not be overlooked because this area is easternmost portion of the Mogok Metamorphic Belt (MMB) and existed between Mogok Metamorphic Belt and Chaung Ma Gyi group to the nearly east.

Regional Geologic Setting

The Myanmar mountain belts and basins record the recent and active slip of India along the western margin of Indochina (or Sundaland). Three main tectonic provinces for Myanmar, all elongated N-S and extending from the East Himalayan Syntaxis in the north to the Andaman Sea into the south, can be identified as (a) The Rakhine Yoma Belt (or Indo Myanmar belt), (b) The Myanmar Central Basin (MCB), located immediately east of the Rakhine Belt, in the central Myanmar Lowlands, (c) The Shan Plateau, with an average elevation of 1000 m is the natural eastward boundary for the MCB and the major topographic relief of the Sino-Myanmar ranges.

The area under the present investigation forms part of the highly deformed metamorphic rocks of so called Mogok Metamorphic Belt (MMB) of Searle and Haq (1964). Further west from the study area, Cenozoic rocks of the Myanmar Central Basin (MCB) is

1 Lecturer, Department of Geology, Banmaw University
2 Lecturer, Department of Geology, Banmaw University

separated from the Mogok Metamorphic Belt (MMB) by the well-known Sagaing Fault. Precambrian and Paleozoic rocks of the western margin of Shan Plateau are existed in the east of the present area.

Fig1. Location map of the study area

Fig.2. Regional geologic setting of the study area and its environ (source: Bender, 1983)

Rock Sequence and Description of Petrographic Units

The rock sequences (Table 1) under this investigation are mainly based on their gross-structural attitude observed in the field. The relative ages of the metasedimentary rock units in the study area are assigned by correlation with the established units in the adjoining areas on the basis of their distinctive lithological characters. The geological map of the study area is shown in figure.

Table (1). Rock Sequence of the Thetkegyin area

Rock unit	**Age**
Metasedimentary rock unit	
phlogopite marble	
diopside-phlogopite marble and calc-silicate rock	
staurolite sillimanite schist	**? Ordovician**
quartzite and sillimanite schist	
garnet schist	

Fig. 3 Geological map of the study area

Garnet Schist Unit

Judging from its nature of outcrops, distribution and structural position, it is designated as the oldest metasedimentary rock in this area. This rock covers the north-eastern part of present area. The rock displays dark grey color on weathered surface and the fresh color of it is gray. This is fine- to medium-grained, hard and compact. Tiny garnets are disseminated in the schistosity plane. Schistosity is well observed in this rock. As a consequence, dip and strike are easily measured. Generally, this rock trends NE-SW direction with north-west dipping.

Microscopic Study

Quartzs, which are the chief minerals, occur as mostly fine xenoblastic to subidioblastic crystals. Plagioclase is found as elongated grains. The grain size varies from 0.1 mm to 0.5 mm. Brown biotite is the abundant mineral in the rock. Orthoclase may be present is small amount or may be absent. Magnetite is found in association with biotite in most specimens. Especially, garnet occurs as rounded porphyroblasts wrapped by quartz and biotite flakes. Average size of the garnet is 1 mm in diameter.

Quartzite and Sillimanite Schist Unit

This rock comprises the quartzite and sillimanite schist. The exposures of quartzite are medium-grained and faintly foliated rocks. It is very hard and compact. Generally, quartzite is pale brown on weathered surface and gray to light gray on fresh surface.

The sillimanite schists of the present investigated area are well foliated, highly jointed and very friable rock type. They are light gray on weathered surface and dark gray on fresh surface. Sillimanite schist is occasionally intercalated with the layer of quartzite.

Microscopic Study

The main constituent mineral of quartzite is quartz. The minor amounts of muscovite, rutile, tourmaline and magnetite are also present in quartzite samples. Ranging in grain size of quartzs is 0.04 mm to 0.06 mm in diameter. Sillimanite schist is mainly composed of quartz, sillimanite and biotite with subordinate amounts of plagioclase and opaque minerals. Quartz forms a granular mosaic with a size ranging from 0.2 mm to 0.6 mm in diameter. Some quartz grain is highly deformed and sutured along the foliation. Sillimanite occurs as xenoblastic to subidioblastic elongate streaks usually finely intergrowthn with quartz. Sillimanite porphyroblasts are oriented parallel to the foliation.

Staurolite-Sillimanite Schist

The exposures of this rock are mainly found at the isolated hill called Pansalong taung (319 m) in central part of the area. It dips to the northwest and trends NE-SW direction.

This rock unit is chiefly composed of staurolite schist and minor sillimanite schist. Spike-liked staurolite crystals are easily seen on the schistosity plane. It is fairly hard and compact, fine- to medium -grained and crystalloblastic in texture. The color of the rock varies between dark to dark gray on weathered surface and dark gray on fresh surface. The surface of exposures is rough and sometimes jagged.

Microscopic Study

The constituent minerals of this rock are staurolite, sillimanite, garnet, biotite, quartz and subordinate amounts of opaque minerals. Staurolites are observed as large porphyroblasts with epitaxial intergrowth with quartzs. Inclusions in staurolite are quartz and minor amount of magnetites. Staurolites are discordant to the main foliation and wrapped by micas flakes. Some of the staurolite is assemble with garnet and some with sillimanite are the prominent feature of this rock.

Diopside Phlogopite Marble and Calc-Silicate Rock

It occurs at the nearly south-east of the Thetkegyin village. Some good exposure is present at Loc: (745780). This rock is trending in NE-SW direction with north-west dipping.

This rock unit constitutes the diopside marble and minor calc-silicate. It is medium- to coarse-grained, fairly hard and compact. Diopside marble is pale green on fresh surface and dark gray on weathered surface. The pinnacles and small solution pits are found in diopside marble. Calc-silicate is well foliated and shows banding due to the light coloured calcite rich layer and dark calc-silicates rich layer.

Microscopic Study

Showing twin lamellae, medium- to coarse-grained equigranular calcite is carrying the tiny diopside granoblasts in this unit.subidioblastic to xenoblastic calcite usually show rhombohedral cleavages. Size varies from 0.2 mm to 0.6 mm in grain size. Diopside showing distinct pyroxene cleavages is subhedral and pale green to dark green in color. Average grain size is about 0.5 mm in diameter. Little amount of graphite is also present in this rocks. Sphene is sometimes observed as xenoblastic in form. Other black colored opaque minerals are disseminated in this marble.

Phlogopite Marble Unit

It is well exposed in the south-eastern part of the area. This unit is thick bedded to massive and foliated in some places. Its foliation may probably be bedding-foliation because bedding of the rock is parallel to the foliation. Banding of the rocks is parallel to the foliation. Therefore, its foliation may be bedding-foliation. Moreover, these rocks contain quartzo-feldspathic veins forming parallel and across the foliation plane. In south easternmost part of the study area, this rock is faulted contact with garnet-schist unit especially in the locality. It is fine- to medium-grained, fairly hard and compact. This unit is whitish gray on fresh surface. The weathered cover is dark gray in color.

Microscopic Study

Granoblastic textures of calcites are well observed in this rock type. The calcite is medium to coarse-grained, cleavage and twin lamellae are also well observed as diopside marble in this area. Although the phlogopite is the widespread minerals in this rock type, other high up minerals are tremolite, sphene and magnetite. Calcites are seen as subidioblastic to xenoblastic form and they show rhombohedral cleavages. The average grain size in diameter is about 0.4 mm. Phlogopite is found as light brown in color and it shows slight pleochroism. It appears as tabular disseminated plates. It is formed as flaky. One set of cleavage is distinct. Parallel extinction can be seen. Little amount of graphite is present.

Petrogenesis

Mineral Assemblages and Metamorphic Facies

The metamorphic rocks of the present study area are widely scattered. Several thin sections cut from various metamorphic rock types were studied to obtain the mineral assemblages and their relationships. The assemblages of coexisting minerals in the metamorphic rock units provide the principal evidence of the metamorphic condition under which they were formed. On the basis of various mineral assemblages, the metamorphic rocks of the study area are belong to the amphibolite facies.

The following relations were especially used in determining the metamorphic facies in this area.

Table (2) Mineral Assemblages and Facies

Mineral Assemblages	**Metamorphic Facies**
Pelitic rocks	
1. Quartz-biotite-muscovite-almandine -plagioclase	Almandine-Amphibolite Facies
2. Quartz-almandine-biotite-muscovite -plagioclase-staurolite	Almandine-Amphibolite Facies
3. Quartz-almandine-biotite-muscovite -plagioclase-staurolite-sillimanite	Almandine-Amphibolite Facies
Calcareous rocks	
1. Calcite +diopside + quartz	Amphibolite Facies
2. Diopside + phlogopite +calcite + quartz	Amphibolite Facies

Types of Metamorphism

The study area is considered to be effective of regional metamorphism. The regional metamorphism is characterized by foliation, lineation, recrystallization, neomineralization and metamorphic differentiation.

Appearances of the medium-grade minerals such as silliminite, staurolite and almandine in schists and the absence of wollastonite in marble and calc-silicate rock in the study area probably suggests that the highest grade of metamorphism was not attained.

Time of Metamorphism

In the study area, the metasedimentary sequence was originally Paleozoic clastic and non-clastic sediments composed mainly of argillaceous, arenaceous and calcareous sediments.

The study area might to be the southern continuation of the Mogok Metamorphic Belt. The age of the metamorphic rocks of the study area is assumed to be contemporaneous with the Mogok Metamorphic Belt on the basis of lateral continuity and lithologic similarities.

Bertrand *et al*. (1999, 2001) present new observations and new mineral ages (eight by the Ar/Ar and nine by the K-Ar methods) from high grade metamorphic and foliated intrusive rocks collected along the MMB of central Myanmar that complete preliminary results were previously published. All 30 ages presented here confirm the Oligocene to Middle Miocene; the ages are young from the Gulf of Martaban in the south to the China-Myanmar border in the north, showing a clear diachronism.

Conclusion

Schist is mainly composed of quartz, plagioclase, orthoclase and biotite. Garnet is also found in some gneiss. The regional metamorphism is characterized by the occurrence of foliation, lineations, and recrystallization in the field. According to the occurrence of the mineral assemblages, lower- to upper- Amphibolite facies and medium to high grade regional metamorphism are observed.

The garnet schist, staurolite schist and sillimanite schist are metamorphosed from pelitic sediments. Metapelites of the study area are situated in the southern continuation of the Mogok Belt. Hence, on the basis of the regional framework, lateral continuity and lithologic similarities, the protoliths of the metapelites from study area is considered to be Lower Paleozoic or Ordovician in age. Moreover, recently published geochronological data indicate that time of metamorphism of the study area may be late Oligocene to early Miocene in age accompanying with early phase of Himalayan Orogeny.

Acknowledgements

We would like to thank Dr Aung Kyaw Thin, Rector and Dr Aye Aye Han, Pro-rector, Banmaw University for their permitting and accepting this research paper. We are greatly indebted to Dr Aung Khin Soe, Professor and Head, Department of Geology, Banmaw

University for his permission and advice on the present manuscript. We also thank our helpmates for their encouraging doing this research.

References

Aung Win (1993), *Petrology of the Phayaungtaung Area, Patheingyi Township*; Univ. Mandalay, unpublished Master´s Thesis.

Bertand, G., Rangin, C., Maluski, Tin Aung Han, Myint Thein, Ohn Myint, Win Maw and San Lwin., (1999). Cenozoic metamorphism along the Shan scarp (Myanmar): evidences for ductile shear along the Sagaing fault or the northward migration of the eastern Himalayan syntaxis?. *Geophysical research letters*, **26,**7,915-918.

Bertand, G., Rangin, C., Maluski, H., Bellon, H. & GIAC Scientific Party., (2001). Diachronous cooling along the Mogok Metamorphic Belt (Shan scarp, Myanmar)the trace of the northward migration of the Indian synthaxis. *Journal of Asian Earth Sciences*, **19,** 649-659.

Bucher, K. and Frey, M. (1994) *Petrogenesis of Metamorphic Ricks*. 6th Edition, Springer-Verlag, Berlin, Heidelberg, New York London, Paris Tokyo, Hong Kong, Brcelona and Budapest.

Kan Saw, (1987). Geology of the northern part of Thakhinma Taung. *Private circulation paper*.

Mitchell, *et al*., (2007). Rock relationships in the Mogok metamorphic Belt, Takton to Mandalay, central Myanmar. *Journal of Asian Earth Sciences*. **29**.

Searle, D.L., and Ba Than Haq., (1964). The Mogok belt of Burma and its relationship to the Himalayan Orogeny. In: *XXII . Intern. Geol. Congr*, pp. 11-20.

Tin Zaw Oo., Kyaw Kyaw Nyein., and Than Thet Mar., (2006). *Petrology of the Thetkegyin-Taungpulu area, Patheingyi Township, Mandalay Division*. (Unpublished M.Sc,Thesis, University of Yadanarbon).

Win Win Maw., (1996). Petrology of the Thetkegyin-Tawzu area, *Patheingyi Township, Mandalay Division*. (Unpublished M.Sc,Thesis, University of Mandalay).

Winter, J. D. (2001) *An Introduction to Igneous and Metamorphic Petrology*. Prentice Hall, U.S.A.

Yardley, B. W. D. (1998) *An Introduction to Metamorphic Petrology*. Longman Ltd. England.

Geology of Taingpa Area, Banmaw Township, Kachin State

San San Win[1], Win Khant[2] and Sandar Win[3]

Abstract

The research area is situated around at Taingpa area, Banmaw Township, Kachin State. It covers part of the topographic map no. 92 H /3. The study area mainly occurs basic igneous rock units exposed along the road from Taingpa taung . The most predominant rock type is olivine basalt. The project area lies on the Mandalay-Myitkyina Opholite belts. This ophiolite belt is associated with significant amount of chromite, nickel, manganese and iron mineralization. The geological investigation is also required for the economic mineralization around the research area. Currently, limestones are used as road and construction materials used and, furthermore to produce cement but it should be taken into consideration about environmental impact on the region to some extent.

Introduction

Location, Size and Accessibility

The research area is situated around northern part of Banmaw Township, Kachin State. The study area is situated between latitude 24° 19' 61" N to 24° 92' 47" N and longitude 97° 10' 97" E to 97° 11' 21" E respectively in one inch topographic map of 92-H /3. It covers approximately 16 square kilometers. This area is located along the eastern part of Ayeyarwaddy River. So, the study area can be reached by motorcycle and boat the whole year round. The location map of the research area is shown in (Fig. 1).

Fig. (1) Location map of Taingpa Taung area and its environs.

1 Assistant Lecturer, Department of Geology, Banmaw University
2 Dr, Associate Professor, Department of Geology, Banmaw University
3 Dr, Professor, Department of Geology, Taunggyi University

Physiography

Physiographyically, the present area lies in mountainous region. The average elevation of Theinpha taung is (750ft) above sea level. The eastern part of the study area is occupied by rugged mountainous area while the rest by rolling hills and alluvial plain. Most of the mountains are trending nearly NE-SW direction. Physiographically, the research area lies in the Eastern High Land and most of the mountains are trending nearly NE-SW direction (Fig.2). Ayeyarwaddy River flows through the research area. Most of the streams are minor streams and they have developed due to the topography and underlying rock units. So, the drainage system of the research area is medium to coarse dendritic drainage pattern.

Fig. (2) Panoramic view of Taingpa Taung area.

Purposes of Investigation

The study area is densely forested and located in Kachin State. Thus, the geological investigation is difficult to carry out. It is geologically still unknown and systematic geological investigation has never been conducted yet.

The main objectives of geological investigation of the proposed area are to investigate the stratigraphic units, to prepare the outcrop map presented in the proposed area in detailed, and to record some possible mineralization.

Methods of Study

The research was done by the field and laboratory studies. Before the field work, literature survey of the previous geological work; study of the regional geology from aerial photographs, satellite images and one inch topographic map were carried out. Geological field works were carried out during October, 2018 and September 2019. The topographic map of 92-H/3 was used as based map to plot all measured geological data. The locations of the lithologic contact were measured by applying GPS. An attempt was made in collecting selected rock samples which would represent each and every lithologic units of the whole area.

Previous Works

The study area has been done a fairly detailed geological mapping, lithostratigraphic classification and some mineralogical accounts by some geologists. Clegg, (1937) described the notes on geology of the second defile of the Irrawaddy River. Einfalt, *et. al*. (1989) carried out the mineral prospecting in the Bhamo-Shwegu area. Hla Htay (2002) systemically reported about the mineralization of Ophiolite Belts in Myanmar. Myint Myint Ye (2011) had done stratigraphy and sedimentary facies of the Mesozoic and Tertiary units in the Nga-O area, Mabein Township, Northern Shan State, for Ph.D Degree in Mandalay University. Khin Khin Lin *et al*. (2014) carried out the Stratigraphy and petrographic investigation of the rock units exposed along Banmaw-Shwegu road (Zinbon Range), Shwegu Township, Kachin State for their research.

Fig. (3) Map showing the physiographic features of the research area.

Regional Geologic Setting

The present area is geotectonically situated in the north-eastern part of the Myanmar eastern highland or Tanintharyi block of Mg Thein (1973). Bender (1983) stated that at the Sino- Burman ranges, east of the Shan Boundary Fault Zone, the tectonically consolidated Precambrian, Paleozoic and Mesozoic sediment sequences have cropped out. This belt extends southward through the Shan Plateau and Tanintharyi ranges and northward to the eastern Himalayas and Yunnan province of China.

The Eastern Highlands is composed of rocks ranging in age from Precambrian to Cenozoic with a variety of rock type. The regional geologic setting of this area is mostly composed of Cretaceous Ophiolite assemblage and carbonate rocks in the central portion and Cenozoic clastic sediments in the western part. Quaternary alluvial sediments are widely distributed in northern and eastern part of the assigned area. The study area is situated in the nearly south of the Banmaw alluvial plain. Furthermore, to the south was commonly cropped out by Shwegu plain. The area is tranversed by several large NNE-SSW trending high angle faults with prominent escarpments which indicate active tectonic faulting. Most of the ranges in the area are bounded by such fault scarps. The regional structural trend is nearly NNE-SSW direction and the dips of most formations are nearly east. The structure in this region is fairly complex by longitudinal faults (nearly N-S trend) and minor cross-faults (nearly NW-SE trend). Strike of the strata in the region also follows the major fault trends. The regional geologic setting of the study area is shown in (Fig.4).

In Myanmar, there are two Ophiolite Lines according to Hutchison (1975) and three Ophiolite Belts to Hla Htay (2002), respectively. They are Naga Hill Line and Mandalay Line of the former and Western Ophiolite Belt, Central Ophiolite Belt and Eastern Ophiolite Belt of the later. NagaHill Line coincides with the Western Ophiolite Belt. Mandalay Line is the combination of present Central and Eastern Ophiolite Belt of Myanmar. Ophiolite is the study of oceanic lithosphere that has been aided by investigation of characteristic rock sequence on land. They usually occur in collisional mountain belts. Their association of deep sea sediments was subsequently thrust up into their continental setting. The ophiolite is mainly composed of four layers according to the geophysical interpretation, including from bottom to top metamorphic peridotite (serpentinization), gabbroic complex sheeted, pillow lava. They are overlain by the radiolarian cherts, pelagic sedimentary rocks, turbidites and carbonate. The complete Ophiolite sequence is shown in Table (1). These belts occur along convergent continental margin with major sedimentary assemblages. Ophiolite is widely distributed in Myanmar, which coincides with the parallelism of major tectonic suture zone between India Plate (oceanic plate) and Eurasia plate (continental plate). Due to the collision of India and Eurasia, Southeast Asia (including Myanmar) had been rotated at least 40° in the clockwise direction to the position, and then a subduction zone was developed between the two plates (Mitchell, 1981). Mandalay-Myitkyina Ophiolite belt (Eastern Ophiolite belt) situated along the western rim of the Sino-Burma ranges extending from Sumprabum in the north, through Myitkyina area and Banmaw, Shwegu, Tagaung to Sagaing- Minwun ranges in the south and terminates at central part of Myanmar. The characteristics of these belts are interested in Cu, Cr, Ni, Fe, Au and Jadeite mineralization.

Fig. (4) Regional geologic setting map of the research area (MGS 2014)

Table (1) Illustration the Diagram of Ophiolite sequence (Source, Winter, 2010)

Distribution of Rock Unit

Basalt

The rock unit exposed in the study is igneous rock unit, especially basalt. Basalt is extrusive basic igneous rock, fine-grained, hard and compact, massive nature and some show alteration in weather surface. Olivine basalt occur in this area (Fig.5) .Basalt makes up the extensive lava flows both continent and ocean floors.

Fig 5(a) Photograph showing lateral view of columnar joint.

Fig 5(b) Photograph showing polygonal structure of columnar joint.

Fig 5(c) Photograph showing dark grey colour and hard and compact nature of basalt.

Fig 5(d) Photograph showing massive nature of basalt.

Fig 5(e) Photograph showing concentric of weather basalt.

Fig 5(f) Photograph showing radial columnar joint.

Fig 5(g) and (h) Photograph showing laterite soil found as base of Taingpa Taung area.

Fig 5(i) and (j) Photographs showing fine-grained and highly jointed nature of olivine basalt.

Explanation

Fig. (6) Geological map of the research area (MGS 2014)

Petrography

Basalt

According to its mineral content, the basalt of the study area is olivine basalt. Megascopically, the rock exhibits fine grained nature and chiefly of composed of plagoclase, clinopyroxene, olivine, orthoclase and Fe mineral .The weather surface of this rock show dark colour and dark grey to dark green on fresh surface. The rocks possess hard, compact nature.

Microscopically, basalt is mainly composed of plagioclase clinopyroxene, olivine, Fe minerals and other accessories mineral. They are euhedral to subheral grained and consist of plagioclase and mafic mineral. Plagioclase and olivine mineral are occur as porphyritic texture.

Fig 7(a) photomicrograph showing the porphyritic texture of olivine basalt (Under XN)

Fig (7b) and (7c) The euhedral and subhedral phynocryst of plagioclase in olivine basalt (a) under PPL and (b) under XN.

Economic Aspect

The mineral deposits in the study area are mainly gold in the form of placer. Placer gold had been found in most river sediments. Local villagers and inhabitants from surrounding area produce placer gold mostly from near Ayeyarwaddy river sand-dune almost the whole year except rainy season. The method that used in production is simple, the panning method. Small amounts or traces of placer gold are also observed at many locations along the Moelay Chaung.

Fig (8a and 8b) Placer gold found nearly in Taingpa taung area.

Summary and Conclusion

This is a preliminary investigation carried out on field trips to give information about the project area that lies on the Mandalay-Myitkyina Opholite belts. They are dismember incomplete ophiolite suite, only two rocks types are commonly observed in this area, metamorphic ultrabasic igneous and carbonate rock with uncommon in basic igneous rocks. Generally, these ophiolites are always associated with regional thrust or near the thrust fault by which they are pushed up to their present position possibly from Cretaceous to Eocene. They are overlain by the Pliocene- Pleistocene age of Irrawaddy Formation, especially sandstone and pebbly sandstone. Ophiolite belt is associated with significant amount of chromite, nickel, manganese and iron mineralization. So, the geological investigation is also required for the economic mineralization around the research area. Currently, limestones are used as road and construction materials. Furthermore, environmental impact on the region should be taken into consideration.

Acknowledgements

We would like to thank Dr. Aung Kyaw Thin, Rector and Dr. Aye Aye Han, Pro-Rector, Banmaw University, for their kind permission to contribute this research paper. We have many thank to Professor and Head, Dr. Aung Khin Soe (Department of Geology, Banmaw University) for his permission to submit this paper to research journal. We also thank our helpmates for their encouragement to do this research.

References

Bender, F., (1983). *Geology of Burma*. Gebruder Bronstraeger, Berlin, 293p.

Chhibber, H.L., (1934). *Geology of Burma*. Macmillian, London, 538p.

Clegg, E.L.G., (1937). Notes on geology of the second defile of the Irrawaddy River. Reg. Geol. Surv. India, Vol.71, 350-358 p.

Einfalt, H.D., Htay, M., Htut, T.Lwin, Z.W.Nyunt, N.sein,(1989). Mineral Prospecting in the Bhamo-Shwegu Area, ECAMS Final report, vol.4.pp.1-64.

Hla Htay, (2002). The Mineralization of Ophiolite Belts in Myanmar, Jour. Myan. Acd. Arts & Science Vol.1, No.2, pp. 199-236.

Hutchison, C.S. (1975) Ophiolite in Southeast Asia. Geol. Soc. Am. Bull. 86, 797-806

Khin Khin Lin, Myo Min, Win Khant (2014), Stratigraphy and petrographic investigation of the rock units exposed along Banmaw-Shwegu car road (Zinbon Range), Shwegu Township, Kachin State, Universities Research Journal (2014), vol.7. No. 1.pp.1-15.

Mitchell, A. H. G.., et al. (1981) Phanerozoic plate boundaries in mainland SE Asia, the Himalays and Tibet. J. Geol. Soc. London. 138, 109-122p.

Myint Myint Ye (2011), Stratigraphy and sedimentary facies of the Mesozoic and Tertiary units in the Nga-O area, Mabein Township, Northern Shan State. Ph.D.(Thesis), Mandalay University, p.123.

Winter.J.D.,(2010). An introduction to igneous and metamorphic petrology.second ed..,prentice Hall, New Jersey.